

REGULATED POWER SUPPLIES

SHOP
COPY



A DIVISION OF



Model 6455A
Power Supply
Instruction & Operating Manual
5

HARRISON LABORATORIES



The information contained in this booklet is intended for the operation and maintenance of H-Lab equipment and is not to be reproduced without written consent of Harrison Laboratories, a division of Hewlett-Packard Company.

PATENT NOTICE*

Patents have been applied for on circuits used in this power supply. Buyer is not licensed to reproduce drawings or to utilize the circuit without written permission from Harrison Laboratories, a division of Hewlett-Packard Company.

CLAIM FOR DAMAGE IN SHIPMENT

This equipment should be tested as soon as it is received. If it fails to operate properly or is damaged in any way, a claim should be filed with the carrier. A full report of the damage should be obtained by the claim agent, and this report should be forwarded to us. We will then advise you of the disposition which is to be made of the equipment and arrange for repair or replacement.

SEE WARRANTY NOTICE ON INSIDE BACK COVER



HARRISON LABORATORIES

The information contained in this booklet is intended for the operation and maintenance of H-Lab equipment and is not to be used or reproduced without written consent of the Harrison Laboratories.

HARRISON LABORATORIES

Div. Hewlett-Packard Company

45 Industrial Road
Berkeley Heights, New Jersey

Area Code 201 464-1234
TWX 201 464-2117

Model 6455A
Power Supply
Instruction & Operating Manual

Model 6455A

REVISION:

Note the following changes in the parts list.

Q3,8,11,14,16 should be N272

Q5 should be B1203

D1,5,8,10,11,12,13,33,36,37,35,39,42,55,56,52,58,54,61,71, 74

73,75,77,80 should be 111S1

D15,16,17,18,19,20,21 should be 1N3253

D3,9,25,26,29,31,41,43,44,45,48,50,60,62,67,69,63,64,79,81

should be 1N484A

T1,3,5 should be H406

D86,87,88,89,90,91 should be T.I.2N684A

Remove C40,41,42 and R70,71,72 should be substituted with

3 G.E. thyrector diodes 6RS21SA2D2

MCN45J

ECN250

ECN171

ECN128

4/6/64

TABLE OF CONTENTS

SECTION	PAGE
I. GENERAL INFORMATION	
1-1 Description	3
1-6 Cooling Equipment	3
1-8 Equipment Supplies	3
1-10 Other Modes Of Operation	4
1-11 Auto-Series	4
1-13 Auto-Parallel	4
1-15 Constant Current Operation	4
II. PREPARATION FOR USE	
2-1 Unpacking and Mechanical Inspection	5
2-4 Line Power	5
2-7 Preparation for Storage and Shipment	5
2-10 Storage	6
2-12 Incoming Inspection and Performance Test	6
2-14 Site Selection and Installation	6
III. OPERATING INSTRUCTIONS	
3-1 Operation	7
3-3 Current Limiting	7
3-6 Remote Sensing	8
3-9 Remote Programming--Voltage	8
3-14 Remote Programming--Current	9
3-20 Auto-Series	10
3-27 Auto-Parallel	11
3-33 Battery Charging	12
3-37 Battery Discharging	13
3-41 Multiple Loading of a Power Supply	13
IV. PRINCIPLES OF OPERATION	
4-1 Block Diagram	14
4-10 Main Rectifying and Filtering Circuits	16
4-13 Auxiliary Supplies and Reference Circuit	16
4-17 Voltage Detector and Error Amplifier	17
4-21 Current Detector and Error Amplifier	18
4-24 Controlled Turn-On Circuit	19
4-26 Silicon-Controlled Rectifier Control Circuits	19
4-27 General	20
4-30 Input Buffer Stages	20

SECTION	PAGE
4-32 Blocking Oscillator	20
4-36 Firing Angle Determination	21
4-39 Reset Operation	22
4-43 Inhibitor Circuit	23
4-47 Metering Circuits	24
4-49 Protection Circuits	24

V. MAINTENANCE

5-1 Performance Check	25
5-2 Equipment Required	25
5-3 Procedure	25
5-4 Mechanical Maintenance	26
5-5 Cooling System Maintenance	27
5-9 Meter Zero-Setting	27
5-11 Printed Circuit Board Access	28
5-16 Printed Circuit Board Servicing	28
5-22 Power Mesh Rectifier Replacement	29
5-24 208VAC Operation	29
5-27 Trouble Shooting	30
5-28 General	30
5-34 DC Voltages	31
5-36 AC Waveforms	32
5-48 Insulation and Continuity Tests	34
5-51 Symptoms and Clues	35
5-60 Detailed Calibration Procedure	37
5-61 General	37
5-68 Required Test Equipment	38
5-70 Procedures	38

VI. PARTS LIST AND FIGURES

6-1 Parts List	44
6-2 Code List of Manufacturers	48
6-3 Figures 1 through 13	

LIST OF ILLUSTRATIONS

1. Block Diagram
2. Firing Ckt. Schematic
3. Power Mesh, Aux. Supplies and Control Ckts.
4. Normal Strapping
5. Remote Sensing
6. Remote Programming
7. Auto-Series
8. Auto-Parallel

- 9. Schematic Diagram
- 10. Typical Waveforms
- 11. Fixed Resistor Programming
- 12. Battery Charging and Discharging
- 13. Test Equipment List & Typical Wiring Diagram

LIST OF TABLES

- 1. Specifications 1

TABLE I --- SPECIFICATIONS

Input: 220/208 VAC, 60 cycles, three phase*

Output: 0-36 VDC, 0-75 ADC

Load Regulation: Combined, less than 0.5% of maximum output voltage for a load

Line Regulation: change from no load to full load or full load to no load combined with an input line change from 210 to 250 VAC or from 250 to 210 VAC.

Ripple and Noise: Less than 0.5% (rms) of maximum output voltage for any combination of line voltage, output voltage, and load current (as measured with a Hewlett Packard 400D voltmeter).

Maximum Ambient Operating Temperature: 50°C

Transient Recovery Time: Less than 50 milliseconds is required for output voltage recovery to within 200 millivolts of the nominal output voltage following a load change from full load to half load or half load to full load. Excluding the initial narrow spike of approximately 100 microseconds duration (significant only for load rise times of less than 0.2 amperes/ μ sec) the transient amplitude will be less than 0.033 volts per ampere output current change.

Temperature Coefficient: Output voltage change per degree Centigrade is less than 0.1% plus 10 millivolts.

Stability: As a constant voltage source, the total drift for 8 hours (after 30 minutes warm-up) at a constant ambient is less than 0.3% plus 60 millivolts.

Overload Protection: An all-electronic, continuously acting, current limit circuit protects the power supply for all overloads, including a direct short across the output terminals. A front panel control permits continuous adjustment of the current limit value from less than 1 ADC to 75 ADC. Secondary protection is provided by a three phase circuit breaker in the input power line.

Controls: A single control makes possible continuous adjustment of the output voltage over the entire range from 0 to 36 volts. The current-limit knob permits the adjustment of the output current to the optimum value for protection of the load device. In addition, this latter control serves as the

output control for constant current operation. The three phase circuit breaker serves as the ON-OFF control and as secondary protection to the instrument.

Meters: A 0-40V voltmeter and 0-80A ammeter are provided on the front panel.

Terminals: Output power connections are made on two rectangular bus bars located at the rear of the supply. Both power supply output terminals are isolated from the chassis and either the positive or negative terminal may be connected to the chassis through a separate ground terminal located adjacent to the output terminals.

Error Sensing and Programming: Remote error sensing can be accomplished from the rear programming strip, and remote programming terminals make possible external control of the output voltage using a 1000 ohm potentiometer and external control of the current limit using a 250 ohm rheostat.

Cooling: An internal blower provides forced air cooling of heat producing components. The blower motor is permanently sealed and requires no lubrication.

Size: 14"H x 17"D x 19"W (standard relay rack mounting).

Weight: 200 Lbs. (approximately)

Finish: Light gray front panel with dark gray case.

*Unit as shipped is wired for 220VAC $\pm 10\%$. Instructions are included for conversion to 208VAC $\pm 10\%$, 60 cps, three phase or unit may be ordered in original purchase contract to be so wired.

SECTION I. GENERAL INFORMATION

1-1 DESCRIPTION

1-2 The H-Lab Model 6455A DC power supply is a completely solid state regulated power supply. It will supply up to 36 volts at up to 75 amperes with continuous adjustment of both voltage and current limiting throughout the output range. The current limit can be set at any current from zero to 80 amperes to protect load elements at any predetermined current level.

1-3 Two meters measure load current and load voltage at the output terminals of the supply. Electronic protection circuits incorporated in this supply are designed to protect the unit against any overload conditions generated by the load device, while protection against failures in the internal main power mesh is accomplished by means of the three phase circuit breaker on the front panel which also serves as the on-off switch for the supply.

1-4 Input power is connected by means of a four-prong lock type connector at the rear of the unit. Output power connections and programming connections for the various modes of operation are also made at the rear of the unit. The output terminals consist of heavy bus bar connected directly to the output capacitors for improved high frequency performance.

1-5 The previously mentioned programming terminals located at the rear of the unit allow the easy adaptation to remote sensing of the output voltage, remote programming of both output voltage and current limiting and to auto-series and auto-parallel modes of operation.

1-6 COOLING EQUIPMENT

1-7 The operation of this unit under high load conditions requires that air be circulated through a compartment containing the heat-producing elements in the circuit. This circulation is by means of a sealed bearing blower located in the compartment with air flowing from one side of the unit to the other. Maintenance procedures concerning this cooling system will be found in the maintenance section.

1-8 EQUIPMENT SUPPLIED

1-9 The equipment supplied consists of only the Model 6455A DC power supply as this supply is complete in itself.

1-10 OTHER MODES OF OPERATION

1-11 AUTO-SERIES

1-12 Two or more Model 6455A's may be connected in series in order to obtain higher output voltages. In this configuration the output voltage capability of the ensemble is n times the output voltage capability of a single 6455A where n is the number of supplies connected in series. The output current capability is that of a single 6455A. Output voltage and current control are retained in a single unit of the ensemble. Refer to section 3 for complete wiring instructions.

1-13 AUTO-PARALLEL

1-14 Two or more Model 6455A's may be connected in parallel in order to obtain higher output currents. Output current capability of this configuration is n times the output current capability of a single Model 6455A where n is the number of units connected in parallel. Output voltage capability is that of a single 6455A. Control of output voltage and current is retained in one unit of the ensemble. Refer to section 3 for complete wiring instructions.

1-15 CONSTANT CURRENT OPERATION

1-16 The operation of the current limit circuit in limiting the output current to a predetermined level can be used to advantage. When in current limit the supply behaves as a constant current source with line and load regulation characteristics of approximately one per cent for each case. The fact that the unit displays automatic crossover between the constant voltage mode of operation and current limiting makes it an ideal supply for applications such as battery charging and discharging. Refer to section 4 for instructions on the use of this supply for these applications.

SECTION II. PREPARATION FOR USE

2-1 UNPACKING AND MECHANICAL INSPECTION

2-2 Inspect the instrument for signs of damage incurred in shipment. This instrument should be tested as soon as it is received. If it fails to operate properly or is damaged in any way a claim should be filed with the carrier. A full report of the damage should be obtained by the claim agent and this report should be forwarded to us. We will then advise you of the disposition to be made of the equipment and arrange for repair or replacement. Include model number and serial number when referring to this instrument for any reason.

2-3 Harrison Laboratories warrants each instrument manufactured by them to be free from defects in material and workmanship. Our liability under this warranty is limited to servicing and adjusting any instrument returned to the factory for that purpose and to replacing any defective parts thereof. Any damage to the instrument upon receipt is due to the carrier. File a claim with the carrier as instructed in the preceding paragraph.

2-4 LINE POWER

2-5 Because of the variety of line power connectors for three phase power sources, neither power cord nor connector are supplied but a twist lock type of connector that mates to the input power receptacle on the unit will be shipped with each new unit. The power cord and the plug for connection to the power source will be supplied by the buyer. Input line current requirements dictate a four wire line cord with each conductor at least number 14 gauge wire.

2-6 The Model 6455A as shipped is wired for 220 volts AC $\pm 10\%$, three phase, 60 cps. 208VAC $\pm 10\%$, three phase, 60 cps may be accommodated by changing the strapping configuration on the input transformers. Refer to section 5 for details on this change. This option can be provided by the factory only when specifically requested by the buyer in his original purchase contract.

2-7 PREPARATION FOR STORAGE AND SHIPMENT

2-8 The best method of packing the instrument is in the original shipping carton with the original fillers packed in the same manner as received from the factory. Therefore, when unpacking note carefully the method of packing and save the original packing material for possible future reuse.

2-9 If the original packing material is not available and it is desired to pack the instrument for storage or shipment, first wrap the instrument in heavy kraft paper to

avoid scratching the paint, then pack the instrument in a cardboard carton with a bursting strength of at least 150 pounds per square inch. Pad the instrument on all sides with at least two inches of rubberized hair. Enclose the cardboard carton in a floating base type wooden carton and strap the carton securely to the base. Provide at least two inches of rubberized hair around the four sides of the box and between the box and the top of the crate.

2-10 STORAGE

2-11 No special precautions are necessary in storage of this unit except the usual protection against mechanical damage, salt air, etc.

2-12 INCOMING INSPECTION AND PERFORMANCE TEST

2-13 This instrument should be checked as soon as it is received to determine that its electrical characteristics have not been damaged in shipment. Refer to section 5 for the performance test.

2-14 SITE SELECTION AND INSTALLATION

2-15 The Model 6455A should be mounted securely in a rack. In environments of vibration the rear of the chassis should also be fastened securely. There should be sufficient space along the sides of the instrument to permit free flow of cool air for cooling. This instrument will fit any standard 19 inch rack and requires a space 14 inches high and approximately 18 inches deep. If the rack is not accessible from the rear, plug the power cable into the input power receptacle, connect the load leads to the output terminals, and make any changes in the programming terminal strip that may be necessary before sliding the instrument into the rack. (If the rack is accessible from the rear, these connections may be made at any time.) Secure the instrument to the rack with screws and cup washers. Connect the power cable to the power source.

NOTE: Do not attempt to loosen the four screw heads in each output bus connected to standoffs passing through the chassis into the instrument. These are both electrical and mechanical connections to the output capacitors and power leads.

SECTION III. OPERATING INSTRUCTIONS

3-1 OPERATION

3-2 No preliminary adjustments are necessary before turning on this instrument other than insuring that the voltage control is full counterclockwise. Connect the wires from the load to the output terminals located at the rear of the instrument. Place the three phase circuit breaker in the ON position and adjust the voltage control (directly underneath the voltmeter) until the voltage on the meter is of the desired value. Adjust the current limit control (directly underneath the ammeter) until the pointer indicates a current value somewhat greater than the expected value of load current.

3-3 CURRENT LIMITING

3-4 The current limit circuit in the Model 6455A serves two purposes. The primary function is the protection of the power supply itself by limiting the load current and thereby effectively limiting the power dissipated internally. The secondary function of the circuit is to provide protection to the load device by limiting the amount of current that may flow into that load device. If only a coarse current limit is required, the calibration on the CURRENT control can be used to set a coarse current limit point. In the instances where the current limit need be set more precisely the following procedure should be followed:

1. Turn the VOLTAGE and CURRENT controls full counterclockwise.
2. Place a short circuit across the output terminals of the supply.
3. Slowly rotate the VOLTAGE control clockwise about one-half turn.
4. Bring up the CURRENT control until the output current as read on the front panel meter reads the desired value of current.
5. Rotate the VOLTAGE control counterclockwise, remove the short circuit, reapply the normal load, and adjust the output voltage to the desired setting.

3-5 As discussed previously, the current limiting circuit makes possible the use of the Model 6455A as a constant current generator in which case the procedure outlined for the precise setting of the current limit point may also be used to set the current level for constant current operation. In this mode of operation the current delivered to the load will be constant within about one percent for variation of load

voltage from zero to 36 volts and within approximately one percent for an input line voltage change of $\pm 10\%$. While in the constant current mode, the VOLTAGE control can be adjusted for overvoltage protection.

NOTE: The operation of the 6455A as a constant current generator is limited to very slow changing or DC loads due to the rather large output capacitor on the unit.

3-6 REMOTE SENSING

3-7 In cases where the load device is remote from the power supply, resulting in poor load regulation at the load terminals, remote sensing can be used. As shipped, the power supply senses the output voltage at the output terminals of the supply and any IR drop in the leads between the power supply and the load causes a consequent degradation of the regulation at the load terminals. By sensing the output voltage at the load device terminals these IR drops are effectively eliminated. The procedure for sensing the load at a remote location is as follows:

1. Turn off the front panel circuit breaker and remove the power cord from the power source.
2. On the barrier terminal strip on the rear of the unit remove jumpers (+S to +) and (-S to -).
3. Connect a pair of leads (#20 gauge wire) between +S and the positive terminal of the remote load and between the -S terminal of the supply and the negative terminal of the remote load.
4. Reconnect the AC power and turn on the power supply.

NOTE: The maximum IR drop that can be contained in the negative bus by means of remote sensing is one volt.

3-8 Although the use of remote sensing improves the DC load regulation at the load, it is important to note that the AC impedance at the load terminals is no better than it was with local sensing. In order to bring about an improvement in the AC impedance it is advisable to place a large electrolytic capacitor across the terminals of the remote load.

3-9 REMOTE PROGRAMMING--VOLTAGE

3-10 The output voltage of the Model 6455A may be controlled from a remote location through the connection of a suitable three terminal programming device to the programming strip at the rear of the unit. The programming device is normally a

voltage from zero to 36 volts and within approximately one percent for an input line voltage change of $\pm 10\%$. While in the constant current mode, the VOLTAGE control can be adjusted for overvoltage protection.

NOTE: The operation of the 6455A as a constant current generator is limited to very slow changing or DC loads due to the rather large output capacitor on the unit.

3-6 REMOTE SENSING

3-7 In cases where the load device is remote from the power supply, resulting in poor load regulation at the load terminals, remote sensing can be used. As shipped, the power supply senses the output voltage at the output terminals of the supply and any IR drop in the leads between the power supply and the load causes a consequent degradation of the regulation at the load terminals. By sensing the output voltage at the load device terminals these IR drops are effectively eliminated. The procedure for sensing the load at a remote location is as follows:

1. Turn off the front panel circuit breaker and remove the power cord from the power source.
2. On the barrier terminal strip on the rear of the unit remove jumpers (+S to +) and (-S to -).
3. Connect a pair of leads (#20 gauge wire) between +S and the positive terminal of the remote load and between the -S terminal of the supply and the negative terminal of the remote load.
4. Reconnect the AC power and turn on the power supply.

NOTE: The maximum IR drop that can be contained in the negative bus by means of remote sensing is one volt.

3-8 Although the use of remote sensing improves the DC load regulation at the load, it is important to note that the AC impedance at the load terminals is no better than it was with local sensing. In order to bring about an improvement in the AC impedance it is advisable to place a large electrolytic capacitor across the terminals of the remote load.

3-9 REMOTE PROGRAMMING--VOLTAGE

3-10 The output voltage of the Model 6455A may be controlled from a remote location through the connection of a suitable three terminal programming device to the programming strip at the rear of the unit. The programming device is normally a

potentiometer but may also be a switching configuration that simulates a potentiometer. Should it be desired that a switching technique be employed, it is necessary to use a shorting-contact arrangement in order to insure that the programming terminals are never open during the switching operation.

3-11 The wiring instructions for the connection of the remote voltage programming potentiometer is illustrated in Figure 6. The procedure consists of removing the straps from terminals A6 to A7 and from A1 to A2 on the programming terminal strip and the connection of a 1000 ohm potentiometer between terminals A7, A2, and -S with the wiper connected to A2 and the clockwise end connected to A7.

3-12 The Model 6455A may also be programmed with external fixed resistors connected between terminals A7, A2, and -S. Figure 11 contains a graph of output voltage versus programming resistors from which the appropriate values of programming resistors may be determined for any desired output voltage. This figure also describes a suggested method for the actual connection of the programming resistors to the programming terminals, including a small wirewound potentiometer so placed to enable the trimming of the output voltage to the exact desired level. This is necessary because of the tolerance of the internal divider network.

NOTE: The values shown on Figure 11 for R_a and R_b are predicated on the fact that the maximum output voltage (VOLTAGE control full clockwise) is set at $37.5 \pm 0.3\text{VDC}$ at the plant. If the maximum voltage is other than 37.5 VDC, adjust to this level with P6 on the rear printed circuit board.

3-13 As shown in Figure 11, the 1000 ohm divider from A7 to -S may be tapped at a number of points to provide a variety of output voltage settings. This configuration requires that the tap point be determined for each particular output voltage level and the divider components determined conforming to these taps, and where the sum of all the parts in series equals 1000 ohms. As in the previous case a small variable resistor is suggested at each tap for the exact setting of the desired output voltage.

3-14 REMOTE PROGRAMMING--CURRENT

3-15 The current limit point of the Model 6455A may be programmed from a remote location by the connection of a suitable resistor to the programming terminal strip at the rear of the unit. Either a fixed resistor (for current limiting at only one level) or a variable resistor may be connected to these terminals.

3-16 Wiring instructions for this particular mode of operation are illustrated in Figure 6. The procedure consists of removing the jumper from A3 to A4 on the

programming terminal strip and the connection of a 250 ohm rheostat (or fixed resistor where current limiting is only required at 80 amperes for all load conditions) between A4 and A5 with clockwise rotation producing increasing resistance on the rheostat.

3-17 If it is found that the remote current limit control is not limiting at 80 amperes with the control full clockwise (probably caused by slight differences in the internal and the remote current limit controls) it may be necessary to calibrate the remote position control. The procedure as outlined in the maintenance section for the calibration of the front panel current control can be used to effect the calibration of the remote control.

3-18 The procedure as outlined above does not completely disable the front panel current control and rotation of this control will cause a slight change in the current limit (approximately 1%). If it is deemed necessary to completely disengage the front panel control, a jumper may be placed on the rear printed circuit board from terminals A5 to 11 on the lefthand side of the board (viewed from the rear) which will accomplish this purpose. If it is not necessary to do this the front panel control should be left in the full clockwise position.

3-19 In cases where a variable remote control is not necessary and the current limit value is less than 80 amperes a screwdriver adjusted 250 ohm rheostat with a locking mechanism should be used. Calibration to the desired limit level can be accomplished by placing a short circuit across the output terminals and setting the control to the desired level by means of the ammeter on the front panel.

3-20 AUTO-SERIES

3-21 Two or more Model 6455A's may be connected in series for higher voltage applications where control of both voltage and current limit of the ensemble is retained in one of the units (master). In this configuration the maximum voltage capability of the ensemble is the sum of the maximum voltage ranges of the units so connected.

3-22 Wiring instructions for the connection of three Model 6455A power supplies are illustrated in Figure 7. In the case where only two units are connected in series, connect the positive output of slave #1 to the positive terminal of the load, and for remote sensing perform the indicated operations on slave #1 instead of slave #2.

3-23 This wiring configuration produces equal voltage contributions from each component of the ensemble. If the components are not balanced, adjust the slave voltages to the same level as the master by adjusting P6 on the slave(s).

3-24 The auto-series configuration can also be used to provide two opposite polarity,

common ground output voltages with one knob control of both voltages. If the two voltages thus provided are different in value, the programming of the slave must be changed from that shown in Figure 7. For two dissimilar voltage levels, connect a 2000 ohm potentiometer between -S and +S on the master with the clockwise end at -S, and connect the wiper to A2 of the slave (no 6K resistor in series). Adjust the potentiometer for the desired level on the slave with the master output voltage set to its proper level. As long as the slave is always the lower output voltage unit, any ratio of master voltage to slave voltage may be set up using this technique of programming.

3-25 Where one load is connected across the output of series connected units (either end of the ensemble grounded), the current limit of the master should be used to control the current limit point of the ensemble. With the configuration providing dual voltages to independent loads, each unit has its own current limit point as programmed at the front panel CURRENT control but the output voltage of the slave will always be proportional to and controlled by the master output voltage.

3-26 The load regulation and line regulation characteristics of two or more 6455A's connected in series will be approximately the sum of the figures for each unit in the ensemble. Transient response should be approximately that of a single unit (50 milliseconds for a change in load from one half to full load).

3-27 AUTO-PARALLEL

3-28 Two or more Model 6455A's may be connected in parallel for higher load current requirements with control of the output voltage and current retained in one of the units (master). In this configuration the maximum current capabilities of the ensemble is the sum of the maximum current capabilities of the units so connected.

3-29 Wiring instructions for the connection of three Model 6455A power supplies are illustrated in Figure 8. In the case where only two units are connected in parallel simply connect them as shown for the master and slave #1 (since slave #2 is exactly the same) in Figure 8.

3-30 This wiring configuration produces equal current contributions from each component of the ensemble. If the components are not balanced adjust for balanced contributions as follows:

1. Slave current greater than master current--adjust P9 on slave.
2. Slave current less than master current--select a value for R7 on slave (use decade resistor--typically--20K ohms).

3-31 If, after connection to the load, the output is unstable (oscillation or ringing) it will probably be necessary to change the value of R76 on the slave unit(s) for

stable output.

3-32 The load regulation and line regulation characteristics of two or more Model 6455A's connected in parallel will be approximately that of a single unit but the transient response to a step change in load of any more than 75 amperes will be poorer than the 50 milliseconds quoted for a single Model 6455A.

3-33 BATTERY CHARGING

3-34 The automatic transition between constant voltage and constant current (current limit) displayed by the Model 6455A makes it an ideal supply for battery charging applications. Using this feature, a battery may be charged at a constant current until the maximum charge voltage is reached at which point the supply will revert to constant voltage and continue to supply a trickle charge current sufficient to maintain full charge (See Figure 12). Thus, the charging operation can be unattended after properly setting the charging rate and the maximum charge voltage and connecting the battery to the output terminals of the supply.

3-35 The procedure for setting the charging rate and full charge voltage on the Model 6455A is as follows:

1. Turn both the VOLTAGE and CURRENT controls full counterclockwise.
2. Place a short circuit across the output terminals and rotate the VOLTAGE control one half turn clockwise.
3. Rotate the CURRENT control to the desired charging rate as read on the front panel ammeter.
4. Rotate the VOLTAGE control full counterclockwise and remove the short circuit.
5. Rotate the VOLTAGE control to the desired full charge voltage as read on either the front panel voltmeter or a more precise voltage standard. The unit may then be connected to the battery terminals, positive to positive and negative to negative.

3-36 By inserting a small resistance in series with one of the load leads from the supply to the battery it is possible to alter the normally rectangular charging plot (Figure 12) in such a manner as to provide a taper charge for the last portion of the charge cycle. The value of this resistance is the difference between the full charge voltage and the voltage at which the tapering is to start, divided by the maximum charging current.

3-37 BATTERY DISCHARGING

3-38 Automatic constant current, unattended discharging of a battery using the Model 6455A requires certain changes in the strapping configuration on the rear programming terminal strip as illustrated in Figure 12. These changes are the removal of the jumpers from A1 to A2 and from A8 to +S on the programming terminal strip and the connection of A2 to the negative terminal of the battery. As noted on the figure, it is important that none of the interconnecting leads between supply and battery become opened due to the possibility of damage to both components. It is equally important to make the connections between battery, power supply and isolation resistor exactly as shown in the figure.

3-39 The operation of the configuration is that when the battery voltage is high, the supply voltage will be low and as the battery discharges the supply voltage increases in order to maintain a constant voltage across R (constant current through R). This condition will prevail until the battery voltage drops to zero at which point the output of the supply will also collapse and no more current will flow through R.

3-40 The procedure for the connection of the components in this configuration is as follows:

1. De-energize the 6455A and rotate the current control full counterclockwise. (The voltage control will be disconnected by step 2.)
2. Remove the designated jumpers (A1 to A2, A8 to +S) and connect A2 to the negative terminal of the battery.
3. Connect the negative terminal of the supply to the positive terminal of the battery.
4. Insert R between the positive terminal of the supply and the negative terminal of the battery, energize the 6455A and rotate the current control to the desired discharge current as read on the front panel meter.

3-41 MULTIPLE LOADING OF A POWER SUPPLY

3-42 It is imperative that each load have two separate leads brought directly back to the power supply terminals when connecting several pieces of equipment or sub-assemblies to the same power supply if full advantage is to be taken of the low impedance of the supply and mutual coupling effects between the equipment being powered are to be avoided.

SECTION IV. PRINCIPLES OF OPERATION

4-1 BLOCK DIAGRAM

4-2 Three power transformers, T7, T8, and T9, supply stepdown three phase AC power to three bridge rectifier circuits containing both fixed rectifiers and silicon-controlled rectifiers whose turn-on characteristics are controlled in such a manner as to supply the desired output voltage and current.

4-3 Transformer T7 also provides stepdown single phase AC to the auxiliary rectifier and filter circuit as shown, the output of which is the unregulated -35VDC auxiliary bias source. This unregulated DC voltage is the input voltage to the reference circuit preregulator circuit, the output of which is -15VDC regulated to approximately 1%. The -15VDC is in turn connected to the reference circuit where the -9.4 VDC $\pm 5\%$ reference voltage is developed. The positive return for the auxiliary rectifier and filter is coupled to the negative output terminal through silicon rectifiers whose low dynamic impedance forward characteristics are used to develop the +2.4 VDC auxiliary source.

4-4 The function of the voltage detector and error amplifier is to compare the reference voltage with the output voltage and to generate a correction signal if the output deviates from its prescribed value. This error signal in turn causes a signal to be generated at the gates of the silicon-controlled rectifiers at a phase angle which will change the output voltage in such a manner as to reduce the error that previously existed to zero. One input to the voltage detector is essentially grounded to the negative output terminal through R18 while the other input is a combination of output voltage and some portion of the -9.4 VDC reference voltage which when no error exists leads to zero volts at this second input terminal to the voltage detector. Therefore, any change in output voltage, whether it is due to a change in the setting of the front panel potentiometer or perhaps due to a change in load current tends to produce a voltage other than zero at this second input terminal. Feedback loop action thereafter through the voltage detector and error amplifier and silicon-controlled rectifiers is such as to reduce this error to zero. Diodes D1 and D5 are protection and/or decoupling diodes. Their decoupling action will be explained further on. R18 provides thermal balance to the voltage detector and also provides an impedance into which the current detector and error amplifier will operate when the unit operates in the current limit mode. The action of the current amplifier will also be explained later in the text. The output of the voltage detector and error amplifier is a DC voltage whose magnitude is a function of the output conditions.

4-5 Transformers T1, T3, and T5 provide stepdown low power windings whose output is used for AC bias purposes and to perform reset operations in each of the three silicon-controlled rectifier control circuits.

4-6 The SCR control circuits receive the output of the voltage detector and error amplifier, mix this with an AC bias provided by the bias and reset transformers (this allows instantaneous correction for changes in line voltage) and generate firing pulses that turn on the silicon-controlled rectifiers in their respective phases at the precise time necessary to fulfill the feedback loop requirements. As can be seen, everything in this region of the circuit is done in triplicate--that is, for each phase there is a power transformer and bridge circuit whose turn-on characteristics are determined by a bias and reset transformer and control circuit intimate to the same phase. For each phase the SCR control circuit must be reset once each half cycle in order to generate an output pulse which is properly synchronized to its particular phase. This reset operation is accomplished by the bias and reset transformer.

4-7 The output of the three bridge rectifiers is rectified DC which is fed into a common input filter consisting of a bank of large electrolytic capacitors. The output of the input filter is connected to the output capacitor with a very small current monitoring resistor (R66 and R67 in parallel) serially connected between the negative output terminal and the negative side of the input filter. The resulting RC network consisting of the monitoring resistor and the output capacitor provides an additional 2:1 reduction in the ripple voltage between the input and output capacitors. Diode D85 is so placed across the output terminals as to be reverse biased through all normal operating conditions but will protect the input and output capacitors should the voltage across the output terminals attempt to reverse in polarity.

4-8 The operation of the current limiting circuit is such that when the output current attempts to exceed a given predetermined value, couples into the feedback loop through D9, and thereafter controls the gate signal supplied to the silicon-controlled rectifiers in such a way as to maintain the current at a constant value through further reductions in the load resistor down to and including a short circuit. This is accomplished by comparing a portion of the reference voltage (determined by the front panel CURRENT control setting) to the IR drop caused by the load current in the series monitoring resistor. If the IR drop due to the load current is smaller in magnitude than the reference voltage sample, diode D19 is back biased and the supply operates as a constant voltage source. If, on the other hand, the monitoring drop attempts to exceed the reference voltage sample, the output of the current detector and error amplifier is such as to close diode D9, thereby inserting the current limiting signal across R18 which effects proper phase control on the SCR's. The reduction in output voltage due to the crossover into current limit operation produces a negative signal on the voltage error input to the voltage detector circuit (D1, D5). This signal is clamped by diode D1, effectively grounding that input. This is the decoupling action as described to this diode earlier in the text.

4-9 Incorporated into the Model 6455A is a circuit which samples the three input

phases (diodes D82, D83, and D84) and in the event of the failure of any phase, operates on the input to all three SCR control circuits in such a way as to lock up the output voltage at zero volts. In the event of a phase failure and resulting lock-up of the output voltage, the unit can be reset by turning the front panel circuit breaker OFF momentarily.

4-10 MAIN RECTIFYING AND FILTERING CIRCUITS

4-11 Three phase 220 VAC 60 cps line voltage is connected to the primary of transformer T7, T8, and T9 through a three phase common trip type circuit breaker which serves the dual function of ON/OFF control and protection against failure in the main power mesh. The wiring on the primary of transformers T7, T8, and T9 may be changed to accommodate three phase 208 VAC, 60 cps as outlined in the maintenance section. Transformer T7 is center tapped on the primary to provide 110 volts for either the 208 or 220 volt input power configuration. This 110 volt tap is used to power the blower and the front panel power indicator light. Each main secondary of these three power transformers is connected to a full wave bridge rectifier consisting of two silicon-controlled rectifiers and two fixed rectifiers (diodes D86 through D97). The output or DC side of the three bridge circuits are in turn connected in parallel and then to a common input filter capacitor bank (consisting of capacitors C33 through C39.). The firing angle of the silicon-controlled rectifiers is controlled in such a manner as to fulfill the load conditions on the output terminals of the supply dictated by the output voltage setting and the load resistor. Resistors R68 and R69 provide a bleed path for the discharge of the input and output capacitors after the unit has been turned off. The resistor capacitor network appearing across the main secondary of the power transformers (C40, C41, C42, R70, R71, and R72) protect the bridge circuit from possible damage due to low energy, high amplitude spikes that may be present on the power line.

4-12 The positive terminal of the input capacitor bank is connected directly to the positive output bus and the positive terminals of the output capacitors (C31 and C32), while the negative side of the input capacitor bank is connected to the negative output bus and the negative side of the output capacitors through a series current monitoring resistor composed of resistors R66 and R67 connected in parallel. The output buses are in themselves pieces of solid copper strap, with the two output capacitors connected directly to these straps for improved high frequency performance. Diode D85 is so placed as to protect the input and output capacitors in the event of a reversal of output voltage on the output terminals (Such a case can occur in auto-series operation when the slave unit is de-energized while the master unit is energized).

4-13 AUXILIARY SUPPLIES AND REFERENCE CIRCUIT

4-14 A fullwave bridge type winding on transformer T7 (terminals 9 and 10) provides

power for the auxiliary voltages and reference voltage. Diodes D18 through D21 and capacitor C6 provide an unregulated -35VDC (all auxiliary voltages and the reference voltage are measured with respect to -S). The positive side of this unregulated auxiliary voltage is returned to the negative output terminal through diodes D15, D16, and D17 whose low dynamic forward impedance is used to advantage in developing a low voltage positive bias source (+2.4VDC). In addition to using the full diode string as a low voltage positive source, a point is picked off between diodes D16 and D17 and used as a slightly less positive voltage source (+1.6VDC). Resistor R25 connected in shunt around this diode string provides a low impedance discharge path for capacitor C6 after the unit has been de-energized.

4-15 Resistor R26, diode D14, and transistor Q5 form an emitter follower type preregulator connected between the -35VDC and the reference circuit and whose output is a negative -15VDC source (test point 20). In this configuration resistor R26 and diode D14 (a 15 volt zener diode) are connected between the -35VDC unregulated auxiliary voltage and the negative output terminal and develop a -15VDC on the base of transistor Q5. The emitter of transistor Q5 will reproduce this -15VDC source almost independently of its collector voltage and collector current. Capacitor C1 is placed across this -15VDC source for ripple reduction. The line regulation of this -15VDC source is approximately 200 millivolts for an input line change of $\pm 10\%$.

4-16 Transistor Q3 and its associated circuitry form a constant current generator whose output is connected to reference diode D4 and any loads connected thereto. Resistor R23 and diodes D11 and D12 are connected in series across the -15VDC source, producing a very stable voltage across the two diodes (any changes in the -15VDC source are attenuated by the ratio of R23 to the forward impedance of the two diodes in series). This well-regulated low voltage is applied across resistor R24 and the emitter diode of transistor Q3 to maintain a constant emitter current in transistor Q3 (and thereby a constant collector current). This constant current is then connected to the reference circuit which includes the reference diode D4 and a variety of essentially constant loads including such things as the programming currents for VOLTAGE and CURRENT controls. Resistor R20 reduces the collector dissipation of transistor Q3.

4-17 VOLTAGE DETECTOR AND ERROR AMPLIFIER

4-18 Transistors Q1 and Q2 form a temperature compensated differential amplifier for the purpose of error detection in the voltage mode. The inputs of this error amplifier are the bases of the two transistors. The base of transistor Q2 is considered the reference base and is connected to -S through a resistor R18 which is selected to provide thermal compensation for the differential amplifier. The base of transistor Q1 is the error input which senses the output voltage through a resistive divider connected between the positive output bus and the reference voltage. Diodes D1 and D5 connected to the base of Q1 perform protection and disconnect functions. The

output of the error amplifier is the collector of transistor Q2. Resistor R15 is connected back to the +2.4VDC source and provides bias current for the two transistors. Resistors R13 and R14 are connected back to the -15VDC source and are the collector load resistors for Q2 and Q1 respectively.

4-19 Resistors R6 and R4 and rheostat P6 form the divider network connected between the positive output bus and the wiper of the front panel voltage control which is in turn connected across the -9.4 VDC reference voltage. The output of this divider network (test point 15) is the error input to the differential amplifier (base of Q1). Since the base of Q2 is clamped to -S through the low resistance R18, any change in the output voltage will produce a change in the voltage at test point 15 and a difference voltage between test points 15 and 16 resulting in an output signal from the error amplifier. Such changes in voltage at test point 15 may be the result of a change in load current or a change in output voltage due to a change in the position of the front panel VOLTAGE control. Only a few millivolts change in voltage between test points 15 and 16 are required to produce a full change in output current. Rheostat P18 and capacitor C28 are connected across the error input of the differential amplifier to provide loop stability. A further enhancement of the DC gain characteristics of the differential amplifier is produced by feeding back some of the output signal at the collector of Q2 to the base of Q1 through resistor R10 and rheostat P5 (positive feedback). In this manner the input impedance of the differential amplifier may be adjusted to infinity. The output of the error amplifier is a DC voltage at the collector of transistor Q2, varying in magnitude from near zero volts for zero output conditions to approximately -10 volts at full load conditions.

4-20 Resistor R21 and rheostat P9 are connected between the base of transistor Q2 and the reference voltage to provide a slight negative bias voltage on test point 16 to insure that the output of the power supply is adjustable to zero volts. Resistor R12 and potentiometer P4 are connected across the -15VDC source with the wiper of P4 diode coupled to the collector of transistor Q2 through diode D3. Potentiometer P4 is set to limit the maximum output signal of the error amplifier stage and is provided to insure stable operation of the supply in case the input line voltage should drop momentarily below the specified limits of operation. Through all normal operating conditions diode D3 is backbiased.

4-21 CURRENT DETECTOR AND ERROR AMPLIFIER

4-22 Transistor Q4 and its associated circuitry form the current detector and error amplifier whose output is connected into the feedback loop if the output current attempts to exceed a predetermined value as programmed by the front panel CURRENT control. A divider network connected between the reference voltage and the negative output bus consisting of resistors R2, R3, potentiometer P22, rheostat P3, and diode D2, provide a small sample of the reference voltage at the wiper of potentiometer P22 (test point 11) which is the front panel CURRENT control. This small reference voltage is compared to the output current (by comparing it to the voltage developed

across resistors R66 and R67 by the output current). If the reference sample is greater in magnitude than the voltage across the current monitoring resistors, there is no output signal from the current detector and transistor Q4 is saturated. If the reference sample and current monitoring drop become equal, transistor Q4 becomes unsaturated with the resulting negative collector voltage forward biasing diodes D8, D9, and D10 and developing a negative signal on the base of transistor Q2. This signal reduces the output voltage, producing a negative signal at test point 15 which is clamped to -S by diode D1 and the output of the voltage detector stage thereafter becomes a function of the load current and not the output voltage. For further decreases in load resistor the DC voltage signal at the collector of transistor Q2 will be changed by the output of transistor Q4 in such a manner as to maintain the output current constant by decreasing the voltage across the load resistor.

4-23 Resistor R3 (selected in the factory) and rheostat P3 are used to calibrate the front panel CURRENT control at the end points. Diode D2 provides thermal compensation for the current detector stage. Resistor R1 and capacitor C5 and resistor R76 and capacitor C7 insure stable operation of the power supply for all output load conditions while in the current limit mode. Diode D13 protects the emitter junction of transistor Q4 against transient, high amplitude, reverse voltage signals. Resistor R19 is the collector load resistor for transistor Q4. A small amount of feedback from the plus bus is connected to the collector of Q4 through resistor R75 for improved load regulation characteristics when in the constant current mode.

4-24 CONTROLLED TURN-ON CIRCUIT

4-25 In order to insure that the current pulses charging the input capacitors are not excessive on turn on, and that the output voltage does not overshoot its preset value, a circuit has been devised to provide controlled turn-on characteristics for the Model 6455A. Capacitor C4 and resistor R17 and diode D6 are connected between the +2.4VDC and the -15VDC. Prior to turn-on, capacitor C4 is in an uncharged condition. At turn-on, the +2.4VDC and -15VDC appear almost instantaneously. The junction of C4 and R17 travels initially to +2.4VDC and as C4 charges through R17, R77 and D7, decays exponentially to -15VDC. The charging current through R77 insures that the input to the SCR firing circuit is initially zero and thereafter increases slowly towards whatever output conditions are dictated by the load resistor. As the negative end of C4 continues toward -15VDC, diode D7 becomes backbiased and the feedback loop takes full control of the output voltage and current. On turn-off, capacitor C4 is rapidly discharged through diode D6 enabling almost immediate re-energizing of the power supply with the same controlled turn-on characteristics.

4-26 SILICON-CONTROLLED RECTIFIER CONTROL CIRCUITS

4-27 GENERAL

4-28 The silicon-controlled rectifier is a solid state device which displays high impedance characteristics with either positive or negative voltage on its anode but which may be switched into a high conductance state when positive voltage is supplied to the anode simultaneously with a gate signal application between its gate lead and its cathode. The gate signal that is used to turn on the device in the Model 6455A is a positive going square wave of about 50 μ seconds duration and whose amplitude is approximately 3 volts, this being the output of the blocking oscillator.

4-29 Each of the input phases has a bridge rectifying circuit associated with it, consisting of two silicon-controlled rectifiers and two static rectifiers. Each of these bridge rectifying circuits in turn has a firing circuit associated with it and synchronized to the same phase. Each firing circuit generates output pulses for its particular set of silicon-controlled rectifiers once each half cycle of input line frequency and so timed that each SCR conducts at identically the same phase angle in their respective phases.

4-30 INPUT BUFFER STAGES

4-31 The input to the three firing circuits is the output of the detector stage (collector-transistor Q2) and is as previously mentioned a DC voltage referenced to -S and varying in amplitude between zero and -10VDC as a function of the output conditions. This varying DC voltage is applied to the base leads of three identical buffer stages (Q9, Q12 and Q15). Resistors in the emitters of these three transistors transform this voltage signal applied to the base into a current whose amplitude is a function of the output conditions and which is then collector coupled into the three firing circuits. Two of these emitter resistors are composed of a series resistor and rheostat, the rheostat being used to compensate for differences in resistors and in transistor emitter diode characteristics. These two rheostats are adjusted in production testing for balanced or nearly balanced 360 cps ripple voltage on the output of the power supply.

4-32 BLOCKING OSCILLATOR

4-33 The blocking oscillator circuit may be viewed as a magnetic monostable multi-vibrator in that with a small trigger input the circuit reverses state completely and regeneratively, remains there for a predetermined period of time and then reverts to its initial state. The blocking oscillators in the Model 6455A (T2, T4, and T6) are triggered into the conducting state by a transistor. Each output winding of the blocking oscillator transformers (terminals 3 and 4 and terminals 7 and 8) is connected between the gate and cathode leads of an SCR through a series current limiting resistor (R30, R31, R41, R42, R52, and R53) with a diode connected in the reverse

fashion between gate and cathode of the SCR to prevent the possible appearance of a reverse spike or pulse on the gate of the SCR (D25, D26, D44, D63, and D64).

4-34 The mechanism by which the blocking oscillator is triggered is by switching the transistors from the non-conducting state into the conducting state (transistor Q7, Q10 and Q13). The trigger transistor has as its collector load one winding of the blocking oscillator transformer while another winding is connected in the base lead of the transistor. The base of the trigger transistor is held at a fixed DC voltage while the signal on the emitter is varied from the non-conducting state into which time blocking oscillator action takes place. The start of current in the emitter of the transistor and the regenerative coupling that exists between the collector and base windings causes the transistor to go into saturation where it remains until the saturation region of the transformer is reached. At this point the coupling action collapses and the transistor returns to the non-conducting state.

4-35 Resistor R40 and capacitor C15 and the similar resistor-capacitors networks in the other firing circuits are local decoupling circuits to prevent a spurious spike from triggering the blocking oscillator into the conducting state at the wrong instant. Capacitor C14 between the base and emitter of Q7 and the similar capacitors placed across the other trigger transistors prevent spurious triggering at that point. Resistor R32 in the base circuit of transistor Q7 and the equivalent resistors in the other firing circuits limit the base current which flows during the blocking oscillator action. Capacitors C11, C17, and C23 are initially charged to approximately 15VDC but upon conduction of the blocking oscillator transistors are discharged to about 13 volts by the base current of the trigger transistors, leaving the bases after blocking oscillator action approximately 2 volts more positive than prior to firing. This prevents the blocking oscillator circuit from retriggering during that same half cycle. At the end of the half cycle these capacitors are reset to -15VDC (test point 36A, 36B, and 36C) for the next half cycle and its required output pulses (See Figure 10-8).

4-36 FIRING ANGLE DETERMINATION

4-37 Determination of the proper firing angle is accomplished by mixing two signals in the emitter circuit of the trigger transistors, these two signals being a reflection of the output conditions and the input line conditions. A ramp voltage whose origin is approximately -15VDC and whose slope is a function of output voltage and output current, is added to a negative going rectified sine wave whose amplitude is a function of the input line voltage.

4-38 The positive going ramp voltage is generated across a capacitor (C12, C18, and C27) by the collector current of the previously described buffer stage transistors (Q9, Q12, and Q15), whose high output impedance insures a linear ramp voltage (Refer to Figures 10-6A and 10-6B). Connected between the emitters of the triggering

transistors and the ramp capacitors is an RC network (R34, R45, and R56, C13, C19, and C24) across which is developed the negative going rectified sine wave, generated by a fullwave rectifying circuit connected to the reset and bias transformer (D32, D34, D51, D53, D70, and D72). This wave shape is displayed in 10-5A and 10-5B. The voltage at the emitter is the sum of this positive going ramp and negative going sine wave (See Figure 10-4A and 10-4B) which at the start of the half cycle is negative going but eventually reverses slope and becomes positive going as the ramp voltage becomes the predominant influence. When the waveshape at the emitter exceeds a given threshold (the emitter becomes positive with respect to the base), the transistor starts to conduct initiating blocking oscillating action. At firing the heavy collector current of the trigger transistor discharges the ramp capacitor sufficiently to prevent refiring in the same half cycle. At the end of the half cycle the ramp capacitor is reset to its starting voltage level and the rectified sine wave goes to zero and starts negative again.

4-39 RESET OPERATION

4-40 The resetting operation is performed by a positive going rectified sine wave referenced to -15VDC (See Figure 10-7), which is generated in each firing circuit through the bias and reset transformer in order to provide synchronization for each firing circuit. The three reset waveshapes appear between terminals 39A, 39B, 39C, and -15VDC.

4-41 As previously mentioned the capacitor in the base circuit of the trigger transistor is reset once each half cycle. As the rectified sinewave approaches the zero crossing region a diode connected between the reset wave and the base capacitor (diode D38, D57, and D76) becomes forward biased and the base capacitor is charged back to -15V from its post-firing voltage of approximately -13V. By the same mechanism, but different from the base reset voltage level by about -1VDC (diodes D36 and D37 forward voltage drop provide this -1VDC offset, and is similarly accomplished in the other firing circuits), the ramp capacitors are reset to their proper starting value by reset diodes D40, D59, and D78. The -1VDC offset between the reset voltage of the base capacitor and the ramp capacitor insures that the trigger transistors are in the non-conducting state at the beginning of each half cycle. Resistors connected between the offset diodes and the -35VDC source provide sufficient current to bring about the charging of the ramp voltage capacitors on the resetting operation (R36, R58, and R47).

4-42 A low forward voltage drop germanium diode is placed from the -15VDC to the output of the reset rectifier circuits which clips the cusp of the reset waveshape at about -0.2VDC, thereby eliminating possible differences in the forward characteristics of the reset rectifier diodes (D28, D47, and D66). This clipping action may be observed as the flattened portion of the cusps as shown in Figure 10-7. A diode is also connected from the -15VDC to the base capacitor (D30, D49, and D68) which

prohibits the base capacitor from discharging more than 0.5VDC from -15VDC due to leakage currents in both the base capacitor and the trigger transistor. A pair of diodes connected in series between the -15VDC and the ramp voltage capacitor (diodes D39 and D41, D58, and D60, and D77 and D79) provide a low impedance discharge path for the ramp voltage capacitor for very light loads and eliminates the condition where only one of a pair of SCR's may be firing. Another pair of diodes connected in the reverse direction between -15VDC and the emitter of the trigger transistor (D33 and D42, D52 and D61, D71 and D80) which limit the positive excursion of the emitter voltage with respect to -15VDC, insures that only one firing pulse will be generated for each half cycle of input line frequency. The ceiling imposed by these diodes is less positive than the voltage to which the base capacitor has discharged due to firing, thus insuring that the trigger circuit will not conduct again until the next half cycle.

4-43 INHIBITOR CIRCUIT

4-44 The purpose of the inhibitor circuit is to place a limit on the rate of change of firing angle during certain abnormal operating conditions such as the sudden application or removal of a short circuit. This circuit insures that the current pulses in the main power rectifiers during these abnormal conditions will not exceed the safe limits as described by the diode manufacturers. This protection is provided by generating a ramp voltage which is in close conformity with the control ramp voltage at maximum output current conditions for all values of output voltage. If the control ramp slope tends to exceed the value prescribed for maximum output current delivery at any particular output voltage, the inhibitor ramp is coupled to the control ramp (D43, D62 and D81), limiting the slope of the control ramp (and thus limiting the current pulse amplitude) until the transient condition has passed. The inhibitor circuit is decoupled through all normal operating conditions. Figure 10-11 displays the limiting action of the inhibitor ramp upon the control ramp.

4-45 An example of the operation of this circuit may be shown in the transient condition following the removal of a short circuit from the output terminals and the resultant charging action to normal output voltage. The removal of the short circuit will cause the feedback loop to demand maximum firing angle to return the output voltage to its normal value. Since the inhibitor ramp is a function only of output voltage and as such is in a low slope condition initially, the inhibitor circuit will limit the current pulses to safe values during the charging action.

4-46 The inhibitor ramp capacitors (C10, C16 and C22) are charged through inputs from both the positive and negative output buses, the positive bus supplying charging current as a function of output voltage while the negative bus supplies charging current for the zero output voltage condition. These inputs are supplied through the series resistor and rheostat pairs connected to test points 35A, 35B, and 35C. The inhibitor ramp capacitors are reset once each half cycle in the same fashion as are the control ramp capacitors (diodes D27, D35, D46, D54, D65, and D73). The ramp voltage is coupled to the control ramp circuit through an emitter follower stage (Q8, Q11 and Q14) and a coupling diode in the emitter of the transistor

(D43, D62, and D81). Resistors R37, R48, and R59 are the collector load resistors for the emitter followers while resistors R38, R49, and R60 are the emitter resistors.

4-47 METERING CIRCUITS

4-48 Both voltmeter and ammeter circuits consist of a 1.0 MA type movement with the calibrating resistors contained on the rear printed board. The voltmeter is connected across the output terminals and is calibrated by means of rheostat P2. The ammeter circuit is connected across the internal current monitoring resistor and is calibrated by means of rheostat P1.

4-49 PROTECTION CIRCUITS

4-50 One of the protection features incorporated in the Model 6455A is the internal connection of 100 ohm resistors between the sensing terminals and the output terminals (R5 and R16). These resistors provide protection should the sensing lead become open (particularly when using remote sensing). These resistors insure that the output voltage will rise only slightly if a sensing lead should become open.

4-51 Another protection circuit incorporated into the Model 6455A insures that no damage will occur internally should one or more of the input phases fail. This circuit monitors the input voltage and upon such a failure clamps the input stages of the SCR control circuits and latches them in the zero output condition. After such a phase failure it may be necessary to reset the protection circuit by turning the front panel circuit breaker off momentarily.

4-52 Diodes D82, D83 and D84 connected to the reset waveform of the three firing circuits and biased by resistor R74 connected back to the -15VDC source provide, at their juncture (test point 23), a mixed signal composed of the tops of the three input phases in rectified form. With the presence of three phases on the input, transistors Q16 and Q17 are biased in the off condition (R27 maintains Q17 in the off position; resistors R64, R65, R73 and R63 maintain transistor Q16 in the off position). In the event of the failure of one or more of the input phases the voltage at test point 23 becomes sufficiently negative to forward bias D23 and D25 resulting in the saturation transistor Q17 and driving the collector to the +1.6VDC at the emitter. This positive signal on the collector in turn closes diode D22 and the resulting current through resistor R28 turns transistor Q16 into the conducting state. The resulting collector current of Q16 latches the base of Q17 in the on condition. Capacitor C2 is placed across the base--emitter diode of transistor Q17 to insure that this circuit will not be triggered by a spike. Capacitor C3 is connected in the base circuit in transistor Q16 to insure that the turn-on characteristics of the instrument are not in themselves latching.

SECTION V. MAINTENANCE

5-1 PERFORMANCE CHECK

5-2 EQUIPMENT REQUIRED

1. Line cord (4 wire) and plug for connection to 220 VAC, 3 phase, 60 cps source (or 208VAC, 3 phase, 60 cps if unit is so wired).
2. Oscilloscope
3. 0.5 ohms load resistor capable of dissipating 200 watts.
4. Shorting strap for output terminals
5. Ohmmeter

5-3 PROCEDURE

1. Measure the resistance to chassis ground from each output bus and from each phase pin on the AC power connector at the rear of the unit (pin with the locating lug is connected to chassis ground internally) with the front panel circuit breaker in the ON position (up). Measured resistance should be in excess of 5 megohms on all measurements.
2. Check the ammeter and voltmeter on the front panel for zero set. If alignment is required, refer to the MECHANICAL MAINTENANCE section.
3. Rotate the front panel VOLTAGE control full counterclockwise and the CURRENT control full clockwise. Check the programming terminal strip on the rear of the unit for normal strapping (See Figure 4). Place the front panel circuit breaker in the OFF position (down). Connect an oscilloscope to the output terminals using a 3 to 2 connector to connect the oscilloscope to the power source. Connect chassis ground to the negative output terminal. Set the vertical amplifier to AC coupling, 50mv/cm; horizontal to 2 milliseconds/cm sweep.
4. Connect the line cord to the power supply, then to the power source.

5. Place the circuit breaker in the ON position (up). Front panel meters should both read zero.
6. Rotate the VOLTAGE control full clockwise. Output voltage should be $37.5 \pm .5$ VDC as read on the front panel voltmeter (ammeter should still read zero). Output ripple should be approximately 25 mv peak to peak, 360 cps (3 phase fullwave rectification of 60 cps line frequency yields 360 cps output ripple).
7. Rotate the VOLTAGE control full counterclockwise, turn off the circuit breaker, connect a 0.5 ohm load resistor to the output terminals, turn on the circuit breaker.
8. Rotate the VOLTAGE control to 10 VDC as read on the front panel voltmeter, ammeter should read 20A, output ripple should be less than 250 mv peak to peak, 360 cps (some 60 cps modulation will also be present in the output ripple).
9. With the output as specified in the last step, turn the unit off, then on again. Output voltage should display a controlled turn on characteristic, taking about a second to reach final value.
10. Rotate the front panel VOLTAGE and CURRENT controls full counterclockwise, de-energize the unit, remove the 0.5 ohm load and place a shorting strap across the output. Remove the oscilloscope leads and energize the unit.
11. Rotate the VOLTAGE control clockwise about one half turn. Rotate the CURRENT control moderately to the full clockwise position. Output current as read on front panel ammeter should be 80 ± 2 amperes.
12. Rotate the CURRENT control full counterclockwise. Output current should be zero amperes (Slight deflection below zero is normal condition).
13. Place the circuit breaker in the OFF position, rotate the VOLTAGE control full counterclockwise, CURRENT control full clockwise, remove the power cord from the power source, disconnect the short circuit across the output terminals.

5-4 MECHANICAL MAINTENANCE

5-5 COOLING SYSTEM MAINTENANCE

5-6 The Model 6455A utilizes forced air cooling on the rectifiers of the power mesh. These diodes are located in a compartment on the top of the unit running the full width of the chassis. As in any forced air cooling system, the compartment should be cleaned regularly (regularity will depend on the cleanliness of the air in the surrounding area). Access may be gained to this compartment by removing the top perforated cover. The compartment should be cleaned with either a vacuum cleaner or with compressed air. Regular cleaning maintains the efficiency of the heat sinks and reduces the possibility of a short circuit to ground due to particle build-up around the diodes.

5-7 Although the blower motor supplied in the unit is a sealed bearing type motor with typical life of 5 years or more under normal operating conditions, the manufacturer has provided an oiling point for the motor bearings. Under normal conditions (ambient temperature, clean circulating air) it won't be necessary to provide oil unless the fan is obviously suffering for lack of it or after a few years of operation and ~~extended life is desired~~. Under conditions of high ambient temperature and/or extremely dusty air, etc., it may be desirable to institute a regular oiling in the preventative maintenance procedures used by the buyer.

5-8 In order to oil the motor bearings, a syringe type oiler must be used. Devices of this type are commercially available from various manufacturers including the blower manufacturer (Rotron Manufacturing Company).

5-9 METER ZERO-SETTING

5-10 The meter pointers must rest on the zero calibration mark on the meter scales when the instrument is at normal operating temperature, resting in its normal operating position and the instrument is turned off. To zero-set the meters proceed as follows:

1. Rotate adjustment screw on the front of the meter clockwise until the pointer is to the left of zero and further clockwise rotation will move the pointer up-scale towards zero.
2. Turn the adjustment screw clockwise until the pointer is exactly over the zero mark on the scale. If the screw is turned too far, repeat steps 1 and 2.
3. Turn meter adjustment screw counterclockwise about 15 degrees to break contact between adjustment screw and pointer mounting yoke, but not far enough to move the pointer back downscale. If screw is turned too far, as shown by the needle moving, repeat the procedure. The meter is now zero--set for best accuracy and mechanical stability.

5-11 PRINTED CIRCUIT BOARD ACCESS

5-12 There are two printed circuit boards in the Model 6455A, both located in the top rear section of the chassis. The board mounted in the vertical position on the rear cross member contains the auxiliary supplies, reference circuit, control amplifiers and protection circuits. The horizontally mounted board in front of and below the vertical board contains the three SCR control circuits.

5-13 Access to both sides of the vertical board may be accomplished by removal of the dust cover on the rear cross chassis and removal of the top perforated cover.

5-14 Removal of the top perforated cover provides access to the top (component side) of the SCR control circuit boards but not to the bottom (copper side). The bottom of the SCR control circuit board can be made accessible by removing the six 6-32 screws located at the corners of the board and about midway along the long edges. After the removal of the screws the board may be rotated to the vertical position using the rear edge as a pivot.

CAUTION: Do not work on printed circuit boards before AC plug is removed and out put capacitors are allowed to completely discharge.

5-15 Care should be taken when working on the SCR control circuit board while it is mechanically disconnected from its supports. Too much strain placed on the wires connected to the board may cause them to break. Check that all wires are connected to the board (after work is completed) before replacing the board in its normal position. Do not operate the instrument unless the SCR control circuit board is in its normal position and the mounting screws are inserted and tightened. This is done to avoid the possibility of a short circuit between chassis ground and the board caused by the grounded standoffs to which the board is mounted.

5-16 PRINTED CIRCUIT BOARD SERVICING

5-17 Excessive heat or pressure can lift the copper strip from the board. Avoid damage by using a low power soldering iron (50 watts maximum) and following these instructions. Copper that lifts off the board should be cemented in place with a quick-drying acetate base cement having good electrical insulating properties.

5-18 A break in the copper should be repaired by soldering a short length of tinned copper wire across the break.

5-19 Use only high quality rosin core solder when repairing etched circuit boards. NEVER USE PASTE FLUX. After soldering, clean off any excess flux and coat the repaired area with a high quality electrical varnish or lacquer.

5-20 When replacing components with multiple mounting pins such as transistor sockets and potentiometers, it will be necessary to lift each pin slightly, working

around the components several times until it is free.

5-21 The procedure for the replacement of a component is as follows:

1. Apply heat sparingly to lead of component to be replaced on the conductor side of board. Remove component.
2. Reheat solder in vacant eyelets and quickly insert a small awl to clean inside of hole or drill out hole with a #60 drill (#50 for medium sized eyelet, #40 for large eyelet).
3. Bend clean trimmed leads on new part and carefully insert through eyelets in board.
4. Hold part against board and solder leads on conductor side of board.

5-22 POWER MESH RECTIFIER REPLACEMENT

5-23 In the event of a failure of one of the rectifier diodes in the three phase full wave rectifier (mounted on heat sinks in upper center of chassis) the following procedure should be followed in the replacement of the faulty diode:

1. Turn the unit off and remove the power cord from the power source.
2. Unsolder the lead(s) from the diode, being careful to note where the wires were connected in the case of a faulty SCR.
3. The diodes are threaded directly into the heat sink. Remove with an open end wrench (9/16" for SCR's, 11/16" for fixed diodes).
4. Start the new diode in the threaded hole, tighten with the proper wrench, being careful to keep the wrench on the hexagonally shaped portion of the diode. Tighten the diode only moderately into the heat sink as excessive torque can cause internal damage to the diode.
5. Reconnect the wires, insuring that the wires are as they were on the faulty unit.

5-24 208VAC OPERATION

5-25 The Model 6455A power supply as shipped is wired for operation on a 220VAC

$\pm 10\%$, 3 phase, 4 wire, 60 cps system. If it becomes necessary to operate on a 208 VAC $\pm 10\%$, 3 phase, 4 wire 60 cps system, certain changes in the wiring of the power transformers contained in the unit will be required. These are as follows:

1. T1, T3, T5 (on SCR control circuit board)--the jumper on the board connected to the point labeled "220V" must be removed and reconnected to the point labeled "208V" (the other end of the jumper remains as connected). Refer to section on PRINTED CIRCUIT BOARD ACCESS and PRINTED CIRCUIT BOARD SERVICING before making the change.
2. T7, T8, T9 (the main power transformers)--the input power lead connected to #4 on the primary must be removed and reconnected to #3. Access can be gained to taps #3 and #4 by removing the eight screws fastening the front panel to the chassis and moving the panel sufficiently to gain access to the taps.

NOTE: Soldering should be done with a large iron (200 watts or more) when accomplishing the main power transformer changes.

5-26 No other changes are needed to provide 208VAC operation.

5-27 TROUBLE SHOOTING

5-28 GENERAL

5-29 PRE-TURN ON CHECKS. Before energizing the unit, check the following items:

1. Presence of 220VAC (or 208VAC) at the plug which connects to the receptacle on the rear of the unit. (Check three phases).
2. Straps on the programming terminal strip on the rear of the unit are placed properly and tightened.
3. Visually inspect for broken leads on the vertical printed circuit board, controls on the front panel and the meters. Inspect the main bridge for broken diodes or loose connections. Inspect both printed circuit boards for burned, charred or broken components.

NOTE: If a component is found to be burned, charred, or broken on the printed circuit board, the cause of such a failure must then be located.

5-30 OPEN LOOP. In certain types of power supply failure (such as uncontrolled

output conditions) it is desirable to open the feedback loop in order to be able to trouble shoot the unit without exceeding voltage limits on the input capacitors, etc. In the Model 6455A, removal of transistors Q7, Q10 and Q13 (blocking oscillator transistors) breaks the loop between the error detector (Q1 and Q2) and the SCR's by disabling the blocking oscillators.

1. If an output still exists after this test, the trouble probably lies in the main power bridge rectifier.
2. If no output exists, the trouble lies in or prior to the blocking oscillator circuit and trouble shooting can proceed safely.

5-31 IN CIRCUIT OHMMETER MEASUREMENTS OF MAIN POWER BRIDGE RECTIFIERS. If a failure is suspected in the power rectifier bridge circuit, a resistance measurement will most often identify the faulty component. Breakdown of the reverse characteristic (or forward characteristic in the case of SCR's) may be determined by measuring the resistance from the lug (anode on rectifier, cathode on SCR) to the stud (heat sink) with the common side of the ohmmeter connected to the stud (heat sink). That is, a resistance of less than 4-5 megohms (as measured on a Simpson Model 269 VOM) indicates a faulty diode.

5-32 Due to the characteristics of a bridge circuit, a resistance measurement test to find a faulty diode will usually indicate two diodes to be at fault. After finding two such apparently bad diodes, it will be necessary to disconnect all the wires to the devices and make further measurements on the now disconnected diodes to determine whether both or only one is faulty.

5-33 When completely disconnected, SCR's should measure high resistance from cathode to anode and from gate to anode with either end connected to the common side of the ohmmeter. The resistance from gate to cathode should be approximately 200 ohms with either gate or cathode connected to the common side of the ohmmeter. The Power rectifiers should read high resistance with the cathode connected to the common side, and low resistance when the anode is connected to the common side. It is important to note that the stud is the cathode of the fixed rectifiers but is the anode of the SCR's.

5-34 DC VOLTAGES

5-35 All measurements as made with a Simpson Model #269 VOM at medium input line voltage and zero output conditions except as indicated to be otherwise. Polarities indicated are for first test point ("FROM") with respect to second test point. All voltages are +10% unless noted otherwise.

	FROM	TO	VOLTAGE	OUTPUT CONDITIONS
1.	22	-	-35VDC $\pm$ 5%	See Note 1
2.	21	-	-15VDC	Any Output, See Note 1
3.	20	-	-15VDC	" " " " "
4.	A7	-S	-9.4 $\pm$ 0.4VDC	" " " " "
5.	26	-	+2.4VDC	" " " " "
6.	28	-	+1.6VDC	" " " " "
7.	18	20	+1.2VDC	" " " " "
8.	A10	-	0 to -.4VDC	(For output current from 0-75A) (See Note 2.)
9.	19	-	0 to -.4VDC	(For output current from 0-75A) (See Note 2.)
10.	15	-S	-0.1VDC	Any Output, See Note 2.
11.	16	-S	-0.1VDC	Any Output, See Note 2.
12.	17	-S	0 to -10VDC	(Will vary from 0 @ no output to) (-10VDC @ full output (36V, 75A)
13.	14	-S	-10.5VDC to -5VDC	(Will vary from -10.5VDC @ no cut-) (put to -5VDC @ full output (36V, 75A)
14.	11	-	-.2VDC to -.6VDC	See Note 3.

Note 1: Peak to peak ripple for -35VDC, -15VDC and -9.4VDC are typically 2V, 100 mv and 5 mv respectively, all 120 cps.

Note 2. Voltage as indicated in lines 9, 10, and 11 are for constant voltage mode. When in constant current, voltage for line 9 will be -2.0 VDC and for line 10 and 11 will be -0.5VDC and will not vary with output current changes.

Note 3: Voltage variations are for front panel CURRENT control setting from 0 to 80 ADC and are as measured when in current limit.

5-36 AC WAVEFORMS

NOTE: Figures 10-3 through 10-12 are repeated every half cycle identically (for constant output conditions). At least two half cycles should be viewed simultaneously (16.6 m sec) to insure this repetition.

5-37 FIGURE 10-1 (A & B)--OUTPUT RIPPLE for two output load conditions. Output ripple frequency is 360 cps with some 60 cps modulation normal.

5-38 FIGURE 10-2 (A & B)--MAIN BRIDGE INPUT VOLTAGE WAVESHAPE across terminals 5 and 6 of T7, T8, and T9. Discontinuities are at the start and cessation of current pulses and are caused by leakage inductance in the transformer. Note that the current pulse width (flat portion) varies with output current and becomes earlier in phase angle for either increased output voltage or current.

5-39 FIGURE 10-3 (A & B)--FIRING PULSE generated by the blocking oscillator circuit and as viewed across the output winding of the blocking oscillator transformers T2, T4, T6 (terminals 3 to 4 or 7 to 8).

5-40 FIGURE 10-4 (A & B)--BLOCKING OSCILLATOR TRANSISTOR, EMITTER WAVESHAPE with respect to -S. Very sharp negative-going change occurs at the firing pulse, waveshape prior to that point is the sum of half sine wave and ramp (Figures 10-5 and 10-6). Second negative-going change (after t_0) is the resetting operation.

5-41 FIGURE 10-5 (A & B)--AC BIAS WAVEFORM is the rectified 60 cps sine wave as developed across C13, C19 and C24 and will vary with line voltage amplitude.

5-42 FIGURE 10-6 (A & B)--CONTROL RAMP VOLTAGE is the voltage generated across capacitors C12, C18 and C27 by the collector currents of transistors Q9, Q12 and Q15, and whose slope is a function of output voltage and current. The sum of waveshape 10-5 and 10-6 is the waveshape presented to the emitter of the blocking oscillator transistors as shown in Figure 10-4. Any change in ramp voltage slope or bias amplitude produces a corresponding change in waveshape at the emitter and a new firing angle.

5-43 FIGURE 10-7--RESET VOLTAGE performs the function of resetting the control ramp capacitor, inhibitor ramp capacitor and base capacitor once each half cycle (in each phase).

5-44 FIGURE 10-8--BLOCKING OSCILLATOR TRANSISTOR, BASE WAVESHAPE is the voltage across capacitors C11, C17 and C23. Voltage will be essentially flat (slope caused by leakage currents, should be no more than $.05V/m \text{ sec}$). Reset operation occurs once each half cycle to level at t_0 .

5-45 FIGURE 10-9--INHIBITOR RAMP VOLTAGE is the voltage generated across capacitors C10, C16, and C22. Slope is slightly exponential and is a function only of output voltage. Reset once each half cycle.

5-46 FIGURE 10-10--INHIBITOR COUPLING DIODE connects the inhibitor circuit to the control ramp under transient load conditions. Waveshape is essentially the

difference between 10-6 and 10-9 as displayed across coupling diodes D43, D62 and D81. These diodes should be back biased over the entire half cycle for all normal operating conditions.

5-47 FIGURES 10-11 and 10-12--OPEN LOOP CONTROL RAMP VOLTAGE is the voltage developed across C12, C18, and C27 with Q7, C10 and Q13 removed. Figure 10-11 shows the ramp with the VOLTAGE and CURRENT controls clockwise. Change in slope of the ramp near t_0 is caused by coupling of the inhibitor circuit and displays the ability of the inhibitor in limiting the slope. Figure 10-12 shows ramp voltage with either VOLTAGE or CURRENT control or both counterclockwise.

5-48 INSULATION AND CONTINUITY TESTS

5-49 As mentioned in the PERFORMANCE CHECK section, good insulation should exist between chassis ground and the input and output busses. In cases where the output busses display a low resistance to chassis ground, insure that the condition is not caused by extreme dirt buildup in the cooling compartment (bridge rectifiers).

5-50 Continuity measurements as outlined below will indicate the condition of the connecting wires between the two printed circuit boards, the SCR's and the output busses. Lack of continuity (in all instances, continuity means zero ohms resistance) can usually be traced to an open lead, most often where that lead is connected to an eyelet on a printed circuit board.

Continuity should exist between:

1. The positive output bus and the + terminal on both printed circuit boards.
2. The negative output bus and the - terminal on both printed circuit boards.
3. Test points 17, 20, 22 and 23 as labeled on each board (that is, continuity between test point 17 on the vertical board and 17 on the horizontal board).
4. Test points 32A, 32B, 32C, 33A, 33B, and 33C, and the gate leads of the SCR's (that is, continuity between 32A on the horizontal board and one gate lead of the two SCR's nearest the fan, with concurrent continuity between 33A and the other SCR gate lead). Firing circuits and their respective SCR's are located in relation to each other. That is, the A circuit controls the SCR's nearest the fan, the B circuit the center SCR's and the C circuit the SCR's farthest from the fan.

5. Test points 31A, 31B, 31C, 34A, 34B, and 34C and the cathodes of their respective SCR's (See Step 4).

5-51 SYMPTOMS AND CLUES

5-52 Poor Load Regulation:

1. Reference voltage (-9.4VDC) may be varying.
2. Insure that the current limit circuit is not starting to limit.
3. Insure the measurements of load regulation are done between +S and -S.
4. Check transistors Q1, Q2, Q4.

5-53 Poor Line Regulation:

1. Check for presence and stability of -9.4VDC, -15VDC and +2.4VDC.
2. Insure that the current limit circuit is not starting to limit.
3. Check transistors Q1, Q2, Q4.

5-54 Excessive Ripple Voltage:

1. Lack of firing on one or more SCR:
 - a. Check the SCR's with ohmmeter
 - b. Check waveforms 10-3, 10-5, 10-6, 10-7.
 - c. Check transistors Q7 through Q15.
2. Check the input and output capacitors for a leaky or shorted unit. Failure will probably be indicated by a blown or protruding membrane on the exhaust valve near the terminals.

5-55 No Output:

1. Check meters
2. Check presence of input power (all phases).
3. Check presence of -35VDC, -15VDC, -9.4VDC and +2.4VDC.
4. Check the strapping on the rear programming terminal strip, particularly the voltage programming terminals.

5. Check the current limit circuit for fault.
6. Check transistors Q1, Q2, Q4, Q16, Q17.
7. Perform continuity measurements between the two printed circuit boards.

5-56 Uncontrolled Output (See OPEN LOOP section):

1. Check the straps on the programming terminal strip.
2. Measure -15VDC, -9.4VDC, +2.4VDC.
3. Check the bridge diodes (static and SCR's) with an ohmmeter for a faulty device.
4. Check transistors Q1, Q2, Q5.
5. Firing circuits:
 - a. Check waveforms 10-3, 10-5, 10-6, 10-7.
 - b. Check transistors Q7 through Q15.
6. Perform continuity measurements between the two printed circuit boards.

5-57 Insufficient Output (voltage and/or current):

1. Check meters
2. If insufficient voltage, insure the current limit is not operating.
3. Check the SCR's with ohmmeter
4. Measure -35VDC, -15VDC, -9.4VDC, +2.4VDC.

5-58 Current Limit Inoperative:

1. Check the straps on the programming terminal strip
2. Check for shorted D13 or C5
3. Check transistor Q4
4. Check for open D8, D9, or D10.

5-59 Excessive Drift:

1. Check the stability of -9.4 VDC
2. Check the VOLTAGE control for excessive noise (P21)
3. Check for cold solder joints and/or noisy resistors (R6, R4, P6)
4. Check transistors Q1, Q2.

5-60 DETAILED CALIBRATION PROCEDURE

5-61 GENERAL

5-62 The following calibration procedure should be performed only after definite indications exist of trouble in the unit or after components have been changed in the circuitry where the adjustments are located. Indiscriminate adjustment of the internal controls to "refine" the settings may actually cause trouble.

5-63 The calibration procedure is composed of seven sections, any one of which may be performed independently.

5-64 The mercury relay connected in series with the heavier of the two load devices allows the independent setting of the load current through each device, insuring that load sharing will be equitable.

5-65 Certain conditions of output loading require that one load device operate at slightly more than its rated capability for short periods of time. A fan so placed as to blow cooling air axially through the load devices is highly recommended to insure against damage to the devices.

5-66 The inhibitor circuit alignment procedure requires the adjustment of an AC waveshape for closure to zero volts across a coupling diode at one point in the period of the waveshape. This is accomplished by using DC coupling on the oscilloscope and adjusting the vertical amplifier such that zero volts deflection is the center line of the screen. The coupling diode voltage is then adjusted such that the waveshape meets the center line of the screen (this will occur at only one point in the waveshape through one half cycle).

5-67 The differential or digital voltmeter serves two functions: that of a voltage standard (0.1%), and as a measuring device for measuring changes in voltage of the order of tens of millivolts. In the case where neither a digital nor differential voltmeter is available, substitute means can be derived to perform the same functions.

Any means that yields an adjustment accuracy of the output voltage meter of 1% or better such as comparison with standard cells, etc., will suffice. After calibrating the front panel voltmeter, it can in itself be used to set the output voltage precisely for the remainder of the procedures (Section 5-71 includes the calibration of the front panel voltmeter and Sections 5-74 and 5-77 require that the output voltage be set to 36 ± 0.3 VDC). Incremental voltages may be measured by connecting a DC source (another power supply or a battery, whose output voltage is approximately equal to the supply output voltage) in opposition to the output of the supply under test and measuring the difference between the two voltages. By adjusting the bucking voltage equal to the supply voltage (within 0.5VDC) the most sensitive scale of a multimeter can be used to detect changes as small as 20 mv in the supply voltage (assuming the bucking voltage stability is significantly better than 20 mv for the measuring period). Section 5-76 requires the measurement of output voltage changes of this order of magnitude.

5-68 REQUIRED TEST EQUIPMENT

5-69 A list of the required test equipment is shown in Figure 13, together with recommended manufacturers and model numbers.

5-70 PROCEDURES

5-71 CALIBRATION OF VOLTAGE PROGRAMMING AND VOLTMETER. The test equipment required for this procedure is Item 5 (See Figure 13).

1. Connect differential/digital voltmeter to +S and -S terminals, rotate CURRENT control clockwise and VOLTAGE control counterclockwise.
2. Energize power supply.
3. Rotate VOLTAGE control clockwise.
4. Set output voltage to 37.5 ± 0.3 VDC (as read on differential/digital voltmeter) with P6.
5. Calibrate front panel voltmeter to voltage measured on differential/digital voltmeter with P2.
6. Rotate VOLTAGE control counterclockwise, turn power supply off and disconnect differential/digital voltmeter.

5-72 FIRING CIRCUIT BALANCE ADJUSTMENT (Balanced 360 cps. output ripple voltage). The test equipment required for this procedure are Items 2 (Model No. 2359

only) and 6. (See Figure 13)

1. Connect oscilloscope to +S and -S terminals, connect load device to output terminals, rotate VOLTAGE control counterclockwise and CURRENT control clockwise.
2. Energize power supply.
3. Set output conditions to approximately 25VDC and 20ADC as read on the front panel meters.
4. Set oscilloscope to 100 mv/cm and 2 msec/cm with AC coupling to vertical amplifier.
5. Adjust P12 and P15 for minimum 60 cps modulation of output ripple (See Figure 10-1A).
6. Rotate VOLTAGE control counterclockwise, turn power supply off and disconnect test equipment.

5-73 CALIBRATION OF CURRENT PROGRAMMING AND AMMETER. The test equipment required for this procedure are items 2, 3, 7, and 8. (See Figure 13).

1. Connect load devices, mercury relay and ammeter to output terminals (See Figure 13), remove R3 from terminals on printed circuit board and connect decade resistor across vacated terminals (set to 90K ohms), rotate VOLTAGE control counterclockwise and CURRENT control clockwise.
2. Energize power supply.
3. Open mercury relay, rotate VOLTAGE control full clockwise, increase load current through still connected load device to approximately 30ADC (set with CURRENT control) at approximately 25VDC output voltage.
4. Rotate VOLTAGE control counterclockwise, close mercury relay, rotate VOLTAGE and CURRENT controls full clockwise, decrease resistance of second load device until output voltage decreases to 25VDC (output current will be less than 75 ADC at this point).
5. Select value for R3 by means of decade resistor such that the output current equals 80 ADC.

6. Rotate CURRENT control full counterclockwise and adjust P3 such that the output current equals 0 ADC.
7. Rotate CURRENT control full clockwise and readjust R3 for 80 ADC output current.
8. Calibrate front panel ammeter to 80 ± 1 ADC as read on external ammeter with P1.
9. Repeat steps 6 and 7 until both conditions are satisfied.
10. Rotate VOLTAGE control counterclockwise, turn power supply off, disconnect test equipment, insert 1/2 watt carbon resistor on printed circuit board for R3 as determined above.

5-74 INHIBITOR CIRCUIT ALIGNMENT. The test equipment required for this procedure are items 1, 2, 3, 4, 6, 8, and 9 (See Figure 13). If the front panel voltmeter has been calibrated, item 5 will not be required. If the front panel ammeter has been calibrated, item 3 will not be required.

1. Connect variable transformer to input power terminals of the power supply, connect load devices, mercury relay and ammeter to output terminals, connect differential/digital voltmeter to +S and -S terminals, connect AC voltmeter to test points 30A and 30B and oscilloscope to test points 37A and 41A (across D43) with test point 37A connected to chassis ground, rotate VOLTAGE control counterclockwise and CURRENT control clockwise.
2. Calibrate oscilloscope vertical amplifier for zero volt deflection to the center of the screen with DC coupling and with 100 mv/cm and 2 m sec/cm.
3. Energize power supply.
4. Set output voltage to 36 ± 0.3 VDC, output current to 75 ± 1 ADC, and input line voltage to 210 VAC (as read on the external monitoring devices). Adjust load sharing in the load devices to 30 ADC and 45 ADC.
5. Adjust waveshape with P11 such that zero volts across D43 occurs once each half cycle at the instant of firing (See Figure 10-10).

6. Rotate VOLTAGE and CURRENT control counterclockwise, connect shorting strap across output terminals in series with ammeter shunt, rotate VOLTAGE control slowly 1/2 turn clockwise, set output current to 75 $\pm$ 1 ADC with CURRENT control and input line voltage to 250 VAC.
7. Adjust waveshape with P10 such that zero volts across D43 occurs once each half cycle at the instant of firing.
8. Rotate VOLTAGE and CURRENT controls counterclockwise, remove shorting strap from output, set conditions as in step 4 and readjust P11 as in step 5.
9. Repeat steps 6, 7, and 8 until conditions are satisfied.
10. Reconnect AC voltmeter to test points 30B and 30C and oscilloscope to test points 37B and 41B (across D62) with test point 37B connected to chassis ground.
11. Repeat steps 4, 5, 6, 7, 8 and 9 while adjusting P14 and P13 instead of P11 and P10. ("B" firing circuit).
12. Reconnect AC voltmeter to test points 30C and 30A and oscilloscope to test points 37C and 41C (across D81) with test point 37C connected to chassis ground.
13. Repeat steps 4, 5, 6, 7, 8 and 9 while adjusting P17 and P16 instead of P11 and P10 ("C" firing circuit).
14. Rotate VOLTAGE control counterclockwise, turn power supply off and disconnect test equipment.

5-75 TRANSIENT RESPONSE ADJUSTMENT. The test equipment required for this procedure are items 2, 3, 6 and 8 (See Figure 13). If the front panel ammeter has been calibrated, item 3 will not be required.

1. Connect load devices, mercury relay and ammeter to output terminals, connect oscilloscope to +S and -S terminals, rotate VOLTAGE control counterclockwise and CURRENT control clockwise.
2. Set oscilloscope to 200 mv/cm and 10 m sec/cm, adjust sweep circuit to trigger from input to vertical amplifier.

3. Energize power supply.
4. Set output voltage to approximately 36 VDC, open mercury relay, set output current to 20 ADC, close relay, adjust output current with second load device to 60 ADC (40 ADC through relay and load device in series connection).
5. Open and close mercury relay and observe output voltage change on oscilloscope. Adjust P18 for output voltage recovery to within 200 mv of output voltage prior to load change within 50 m sec for both loading and unloading transient.
6. Rotate VOLTAGE control counterclockwise, turn power supply off, and disconnect test equipment.

5-76 POSITIVE FEEDBACK ADJUSTMENT. (Load regulation adjustment.) The test equipment required for this procedure are items 2, 3, 5 and 8 (See Figure 13). If the front panel ammeter has been calibrated, item 3 will not be required.

1. Connect differential/digital voltmeter to +S and -S terminals, connect load devices, mercury relay and ammeter to output terminals, rotate VOLTAGE control counterclockwise and CURRENT control clockwise.
2. Energize power supply.
3. Set output voltage to approximately 36 VDC, open mercury relay, set output current 25 ADC, close relay, adjust output current with second load device to 75 ADC (50 ADC through relay and load device in series connection).
4. Open and close mercury relay and observe output voltage change on differential/digital voltmeter. Adjust P5 for an output voltage change of less than 20 mv for a load change of 50 ADC.
5. Rotate VOLTAGE control counterclockwise, turn power supply off and disconnect test equipment.

5-77 MINIMUM FIRING ANGLE ADJUSTMENT. The test equipment required for this procedure are items 1, 2, 3, 4, 5, 6, and 8 (See Figure 13). If the front panel ammeter and voltmeter have been calibrated, items 3 and 5 will not be required.

1. Connect variable transformer to input power terminals of the power supply, connect load devices, mercury relay and

ammeter to output terminals, connect differential/digital voltmeter and oscilloscope to +S and -S terminals, connect AC voltmeter to test points 30A and 30B, rotate VOLTAGE control counterclockwise and CURRENT control clockwise.

2. Set oscilloscope to 100 mv/cm and 2 m sec/cm with AC coupling to the vertical amplifier.
3. Energize power supply.
4. Set output voltage to 36 ± 0.3 VDC, output current to 75 ± 1 ADC and input line voltage to 205 VAC (as read on external monitoring devices). Adjust load sharing in the load devices to 30 ADC and 45 ADC (75 ADC total).
5. Adjust P4 until output voltage begins to decrease (starting at the full clockwise position) then back off adjustment to point where output voltage is unaffected.
6. Reduce input line voltage until output ripple increases in magnitude, then raise input line voltage and observe that ripple voltage returns to normal magnitude and frequency before line voltage reaches 210 VAC.
7. Rotate VOLTAGE control counterclockwise, turn power supply off and disconnect test equipment.

6-1 PARTS LIST

Symbol	Quantity	Description	Value and/or Mfg. Part No.	Mfg. Key	A*
T7, 8, 9	3	Transformer-Powe	H350	H-Lab	2
T1, 3, 5	3	Transformer-Bias	H371	H-Lab	2
T2, 4, 6	3	Transformer-Pulse	H286A	H-Lab	2
Q5	1	Transistor-Power	2N1137A	83298	2
Q1, 2, 4, 9, 12, 15, 17	7	Transistor-GE-PNP	2N1471	IND	15
Q7, 10, 13	3	Transistor-GE-PNP	2N1377	01295	5
Q3, 8, 11, 14, 16	5	Transistor-GE-PNP	2N1304	01295	5
D92, 93, 94, 95, 96, 97	6	Rectifier-Sil Power	1N1193A	16758	10
D86, 87, 88, 89, 90, 91	6	Rectifier-SCR	2N684	03508	10
D85	1	Rectifier-Sil Power	1N1183A	16758	2
D18, 19, 20, 21	4	Rectifier-Sil	PA320A	GI	10
D3, 9, 13, 25, 26, 29, 31, 41, 43, 44, 45, 48, 50, 60, 62, 63, 64, 67, 69, 79, 81	21	Rectifier-Sil	PA305A	GI	30
D28, 32, 34, 47, 51, 53, 66, 70, 72	9	Rectifier-GE	1N91	03508	10
D1, 5, 6, 7, 22, 24, 27, 30, 38, 40, 46, 49, 57, 59, 65, 68, 76, 78, 82, 83, 84	21	Rectifier-Sil	1N484A	GI	20
D8, 10, 11, 12, 15, 16, 17, 33, 35, 36, 37, 39, 42, 52, 54, 55, 56, 58, 61, 71, 73, 74, 75, 77, 80	25	Diode-Sil	F1105 or PA305A	GI	25
D2	1	Diode-Sil	1N2326	02735	2
D4	1	Diode-Zener	1N2163	USS	3
D14	1	Diode-Zener	1N719	99942	2
D23	1	Diode-Zener	1N753A	04713	3

Symbol	Quantity	Description	Value and/or Mfg. Part No.	Mfg. Key	A*
P21	1	Potentiometer-wirewound	1K, 2W Type WP	CTA	2
P22	1	Potentiometer-wirewound	250, 2W Type WP	CTA	2
P5, 9	2	Potentiometer-composition	100K, Type 70	71450	2
P10, 11, 13, 14, 16, 17	6	Potentiometer-composition	25K, Type 70	71450	5
P2	1	Potentiometer-wirewound	5K, Type 110	11236	2
P4, 6, 12, 15	4	Potentiometer-wirewound	1K, Type 110	11236	2
P1, 3, 18	3	Potentiometer-wirewound	250, Type 110	11236	2
C31, 32, 33, 34, 35, 36, 37, 38, 39	9	Capacitor-electrolytic	20,000 μ fd @ 45VDC #D33486	56289	10
C6	1	Capacitor-electrolytic	490 μ fd @ 65VDC #D32872	56289	2
C7	1	Capacitor-electrolytic	500 μ fd @ 3VDC #30D120A1	56289	2
C28	1	Capacitor-electrolytic	200 μ fd @ 15VDC #30D174A1	56289	2
C1, 4	2	Capacitor-electrolytic	100 μ fd @ 25VDC #30D188A1	56289	4
C5	1	Capacitor-electrolytic	750 μ fd @ 0.5VDC #D32483	56289	2
C15, 21, 26	3	Capacitor-electrolytic	20 μ fd @ 50VDC #D26637	56289	4
C13, 19, 24	3	Capacitor-electrolytic	5 μ fd @ 50VDC #30D193A1	56289	4
C3	1	Capacitor-electrolytic	20 μ fd @ 15VDC #30D167A1	56289	3
C2	1	Capacitor-paper	0.1 μ fd @ 200VDC #148P10492	56289	1
C10, 12, 16, 18, 22, 27, 40, 41, 42	9	Capacitor-paper	1.0 μ fd @ 200VDC #118P10592S3	56289	5
C11, 17, 23	3	Capacitor-paper	.082 μ fd @ 100VDC #148P82391	56289	3
C14, 20, 25	3	Capacitor-mica	510 μ fd @ 200VDC	84171	3
R68, 69	2	Resistor-wirewound	40 ohms, 65W, Type 817	WL	4
R66, 67	2	Resistor-shunt	0.01 ohms 50ADC, Deciohm**	HH	4
R22	1	Resistor-wirewound	250 ohms, 5W	WL	2
R70, 71, 72	3	Resistor-wirewound	25 ohms, 5W	WL	2
R4	1	Resistor-wirewound	7.5K, 3W #242E7525**	56289	2
R6	1	Resistor-wirewound	2K, 3W, #242E2025**	56289	2
R36, 47, 58	3	Resistor-carbon	1.3K, 1W	01121	3
R74	1	Resistor-carbon	15K, 1/2W	01121	1
R75	1	Resistor-carbon	200K, 1/2W	01121	1
R27	1	Resistor-carbon	24K, 1/2W	01121	1

Symbol	Quantity	Description	Value and/or Mfg. Part No.	Mfg. Key	A*
R26, 38, 49, 60, 65	5	Resistor-carbon	3K, 1/2W	01121	4
R24	1	Resistor-carbon	39, 1/2W	01121	1
R9, 23	2	Resistor-carbon	3.3K, 1/2W	01121	2
R5, 16, 20, 25, 34, 45, 56, 76	8	Resistor-carbon	100, 1/2W	01121	5
R21	1	Resistor-carbon	51K, 1/2W	01121	1
R2, 57	2	Resistor-carbon	6.8K, 1/2W	01121	2
R14	1	Resistor-carbon	5.1K, 1/2W	01121	1
R1	1	Resistor-carbon	330, 1/2W	01121	1
R19, 40, 51, 62	4	Resistor-carbon	2.4K, 1/2W	01121	3
R12	1	Resistor-carbon	510, 1/2W	01121	1
R13	1	Resistor-carbon	10K, 1/2W	01121	1
R18	1	Resistor-carbon	1.6K, 1/2W	01121	1
R15	1	Resistor-carbon	1K, 1/2W	01121	1
R10	1	Resistor-carbon	91K, 1/2W	01121	1
R11	1	Resistor-carbon	36K, 1/2W	01121	1
R8, 63	2	Resistor-carbon	200, 1/2W	01121	2
R32, 43, 54	3	Resistor-carbon	680, 1/2W	01121	2
R39, 50, 61	3	Resistor-carbon	33K, 1/2W	01121	2
R33, 44, 55	3	Resistor-carbon	27K, 1/2W	01121	2
R37, 48, 59	3	Resistor-carbon	430, 1/2W	01121	2
R30, 31, 41, 42, 52, 53	6	Resistor-carbon	22, 1/2W	01121	4
R3, 7	2	Resistor-carbon	Shunt (determined in testing)	01121	
R35, 46	2	Resistor-carbon	6.2K, 1/2W	01121	2
R64	1	Resistor-carbon	30K, 1/2W	01121	1
R28, 29	2	Resistor-carbon	7.5K, 1/2W	01121	2
R73	1	Resistor-carbon	2.7K, 1/2W	01121	1
R17	1	Resistor-carbon	20K, 1/2W	01121	1
R77	1	Resistor-carbon	3.9K, 1/2W	01121	1
	1	Circuit Breaker	20Amps, 120/240VAC, 60cps #3X0415	HN	2
L1	1	Indicator	#1010-A1	IDI	1

Symbol	Quantity	Description	Value and/or Mfg. Part No.	Mfg. Key	A*
	1	Fan	"Muffin" with Venturi #FIC2	82877	1
	1	Voltmeter	0-40VDC, Flush Type	H-Lab	1
	1	Ammeter	0-80ADC, Flush Type	H-Lab	1
	2	Knob	Bakelite with Pointer G-74G	28480	2
	1	Plug	4 wire, #7408G	HU	1
	1	Connector	4 wire, #7413G	HU	1
	13	Socket, transistor	#3305	91662	5

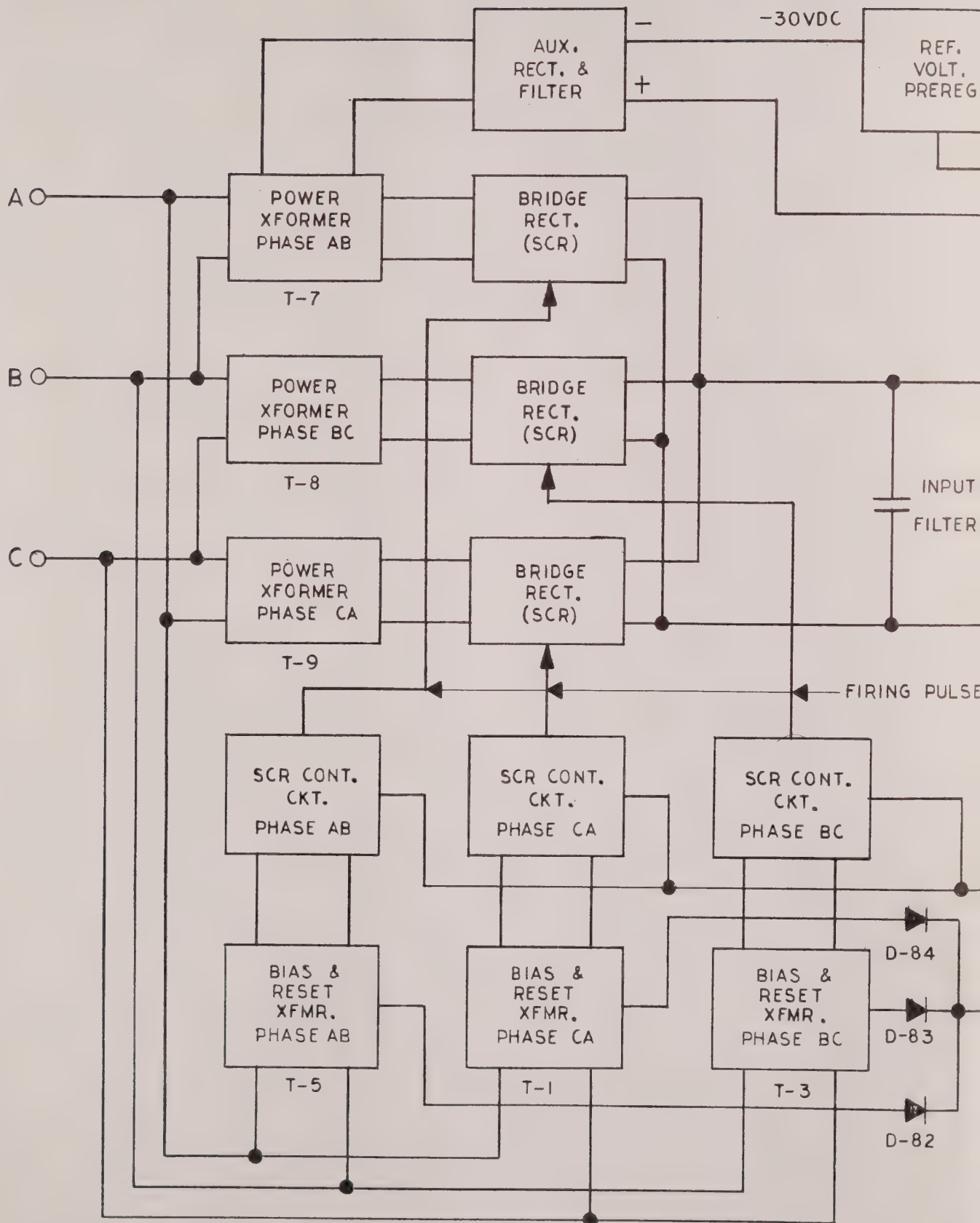
Note: All carbon resistors $\pm 5\%$

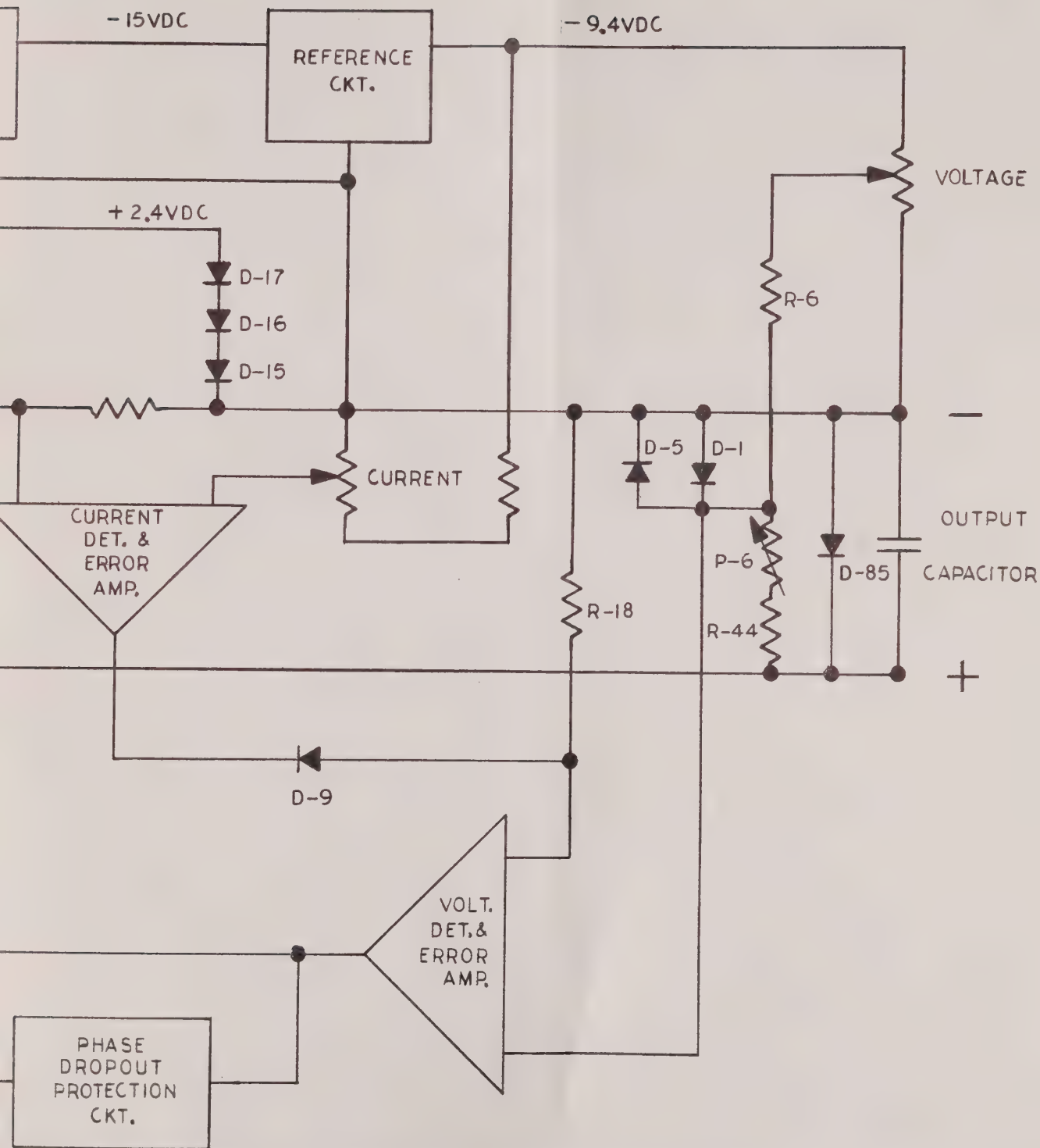
**20 part/million temperature coefficient wire.

A* -- Recommended Spares/10 units/year.

6-2 CODE LIST OF MANUFACTURERS

01121	Allen Bradley Company, Milwaukee, Wisconsin
01295	Texas Instruments Inc., Semiconductor Comp. Div., Dallas, Texas
02735	Radio Corporation of America, Semiconductor & Materials Div. Somerville, New Jersey
03508	General Electric Co., Semiconductor Prod. Dept., Syracuse, New York
04713	Motorola, Inc., Semiconductor Prod Div., Phoenix, Arizona
11236	CTS of Berne, Inc., Berne, Indiana
16758	Delco Radio Div. of GM Corporation, Kokomo, Indiana
28480	Hewlett-Packard Co., Palo Alto, California
56289	Sprague Electric Co., North Adams, Massachusetts
71450	CTS Corporation, Elkhart, Indiana
82877	Rotron Manufacturing Co., Inc., Woodstock, New York
83298	Bendix Corporation, Red Bank Div., Red Bank, New Jersey
84171	Arco Electronics, Inc., New York, New York
91662	Elco Corporation, Philadelphia, Pennsylvania
99942	Hoffman Semiconductor Div. of Hoffman Electronics Corp., Evanston, Illinois
GI	General Instrument Corp., Semiconductor Div., Newark, New Jersey
H-Lab	Harrison Labs., Div. of Hewlett-Packard, Berkeley Heights, N. J.
IND	Industro Transistor Corporation, New York, New York
USS	U.S. Semiconductor Prod., Inc., Phoenix, Arizona
CTA	CTS of Ashville, Skyland, North Carolina
WL	Ward Leonard Electric Company, Mt. Vernon, New York
HH	Hardwick-Hindle, Inc., Newark, New Jersey
HN	Heinemann Electric Company, Trenton, New Jersey
IDI	Industrial Devices, Inc., Edgewater, New Jersey
HU	Harvey Hubbell, Inc., Bridgeport, Connecticut

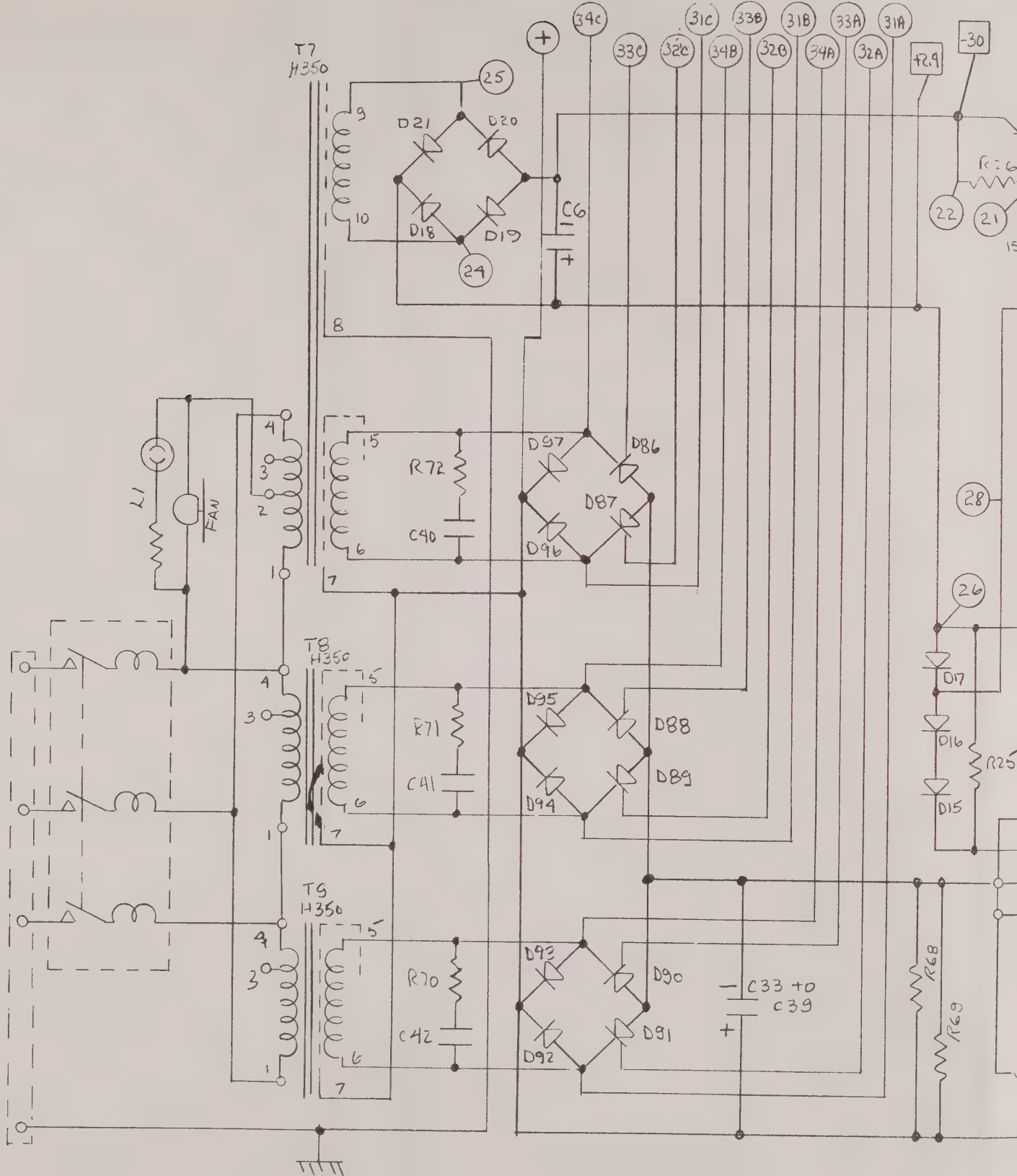


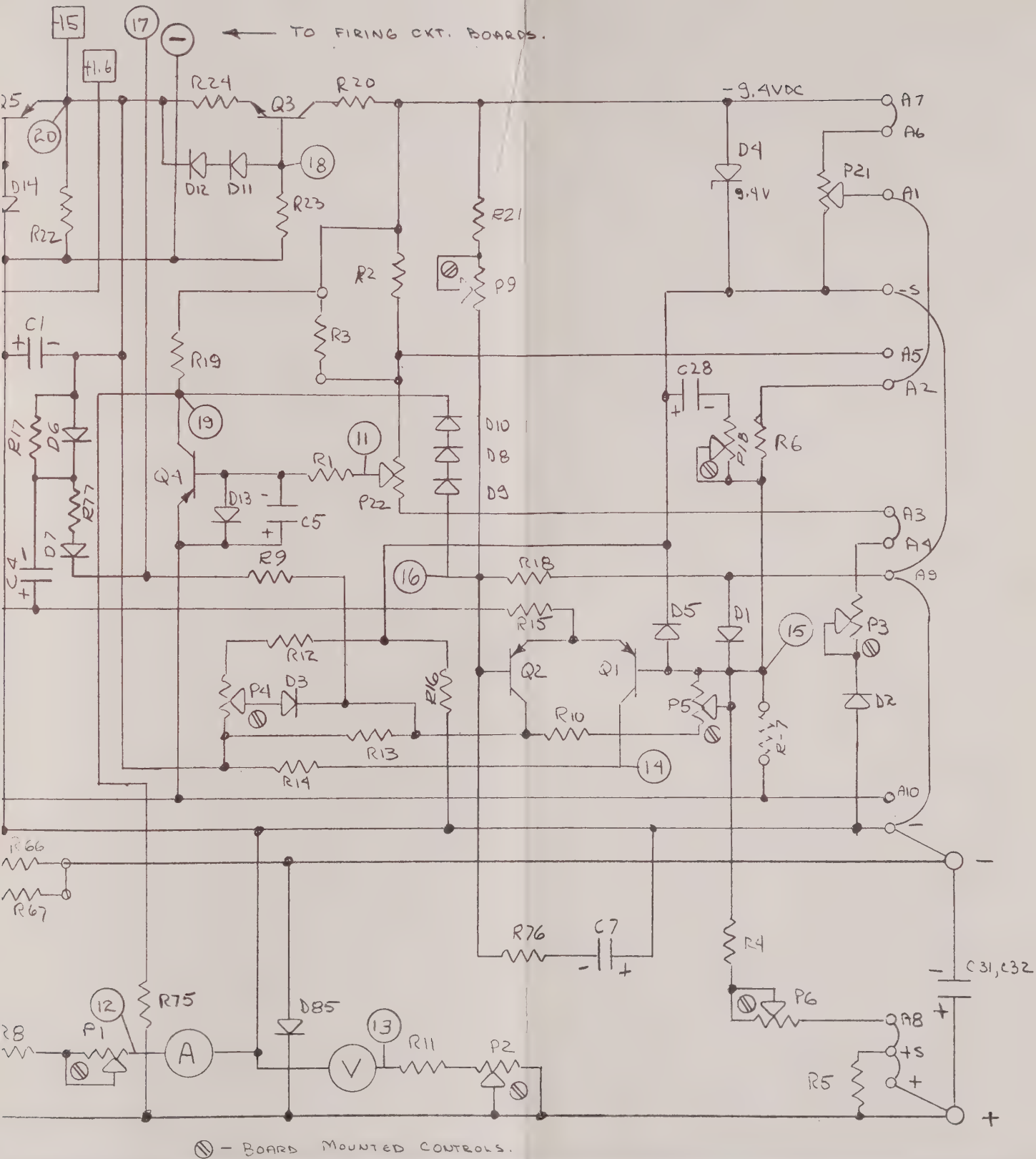


JOB NO. 6455A
DWN 10-5-62 *ms*

HARRISON LABORATORIES, INC.
45 INDUSTRIAL ROAD
BERKELEY HEIGHTS, N. J.

TITLE **FIG 1**
MODEL 6455A BLOCK DIAGRAM





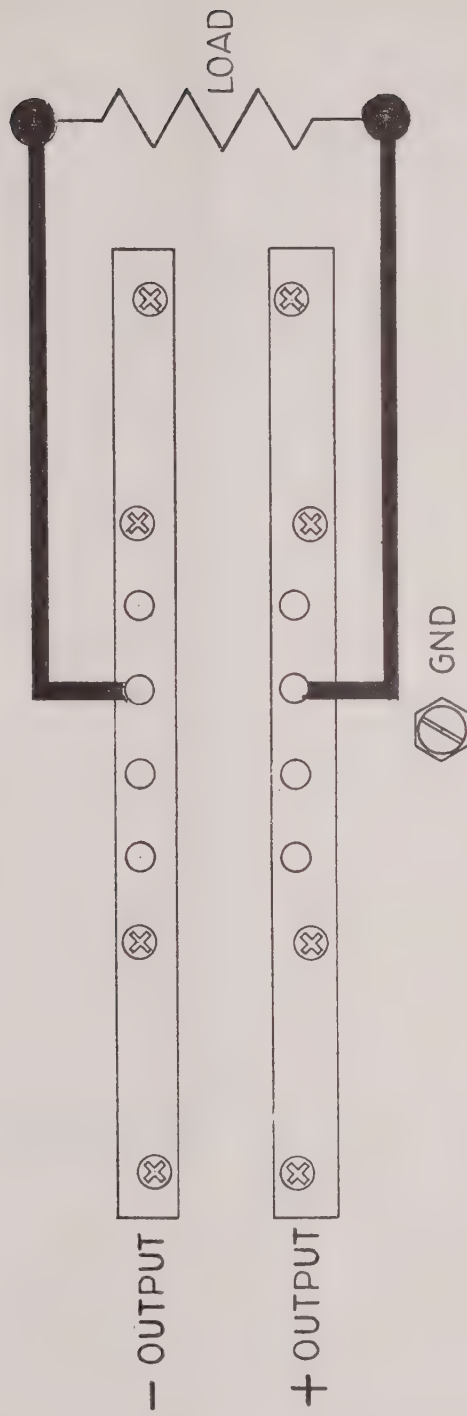
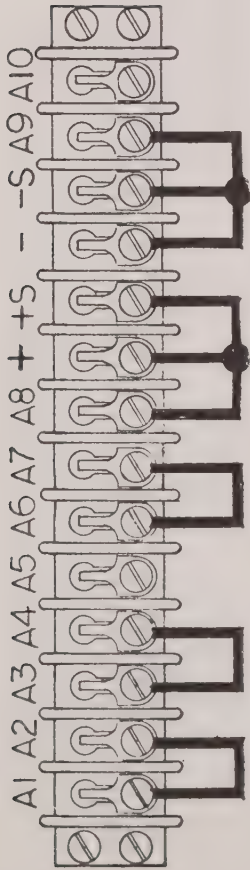
HARRISON LABORATORIES, INC.

45 INDUSTRIAL ROAD
BERKELEY HEIGHTS, N. J.

TITLE FIG 3 MODEL 6455A
POWER MESH, AUX SUPPLIES &
CONTROL CKTS

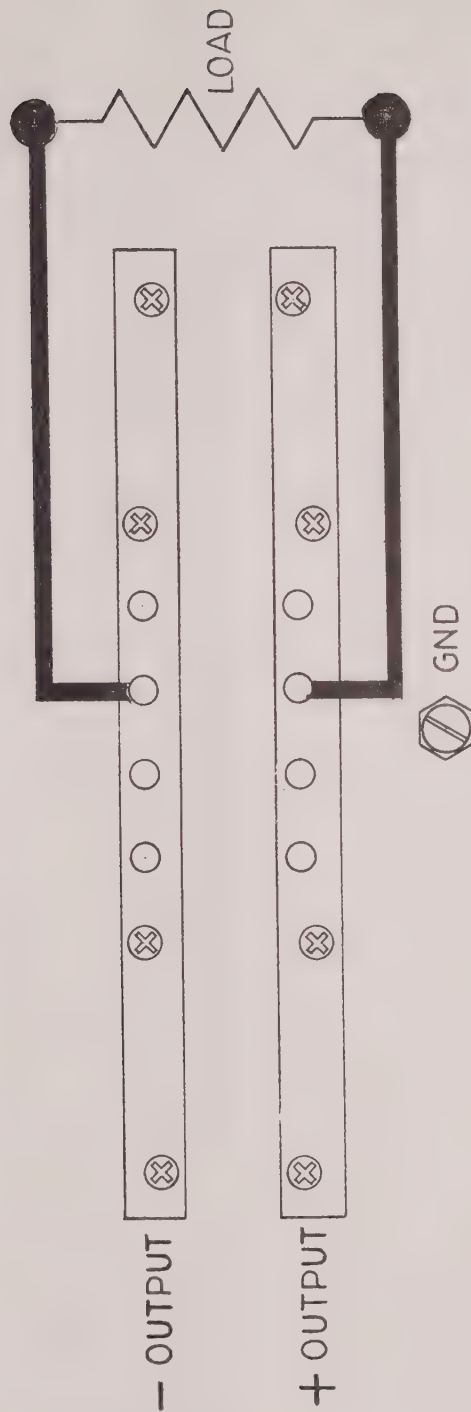
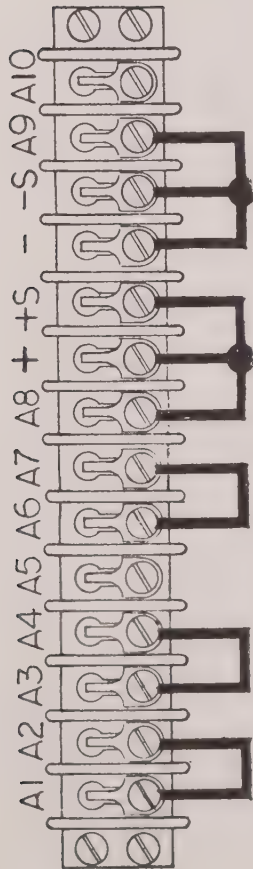
JOB NO.

DRAWN 9/27/62
RAB



NORMAL STRAPPING (AS SHIPPED)
 LOCAL SENSING
 LOCAL PROGRAMMING.

J08 NO. 6455A	DWN 10-5-62	EVA 3-11-63 REVERSE + + + S RUN +	TITLE	
			NORMAL STRAPPING	
			FOR	FIG 4
			MODEL 6455A	
HARRISON LABORATORIES				
BERKELEY HEIGHTS, N.J.				
DIV. OF HEWLETT PACKARD				



NORMAL STRAPPING (AS SHIPPED)
LOCAL SENSING
LOCAL PROGRAMMING

TITLE

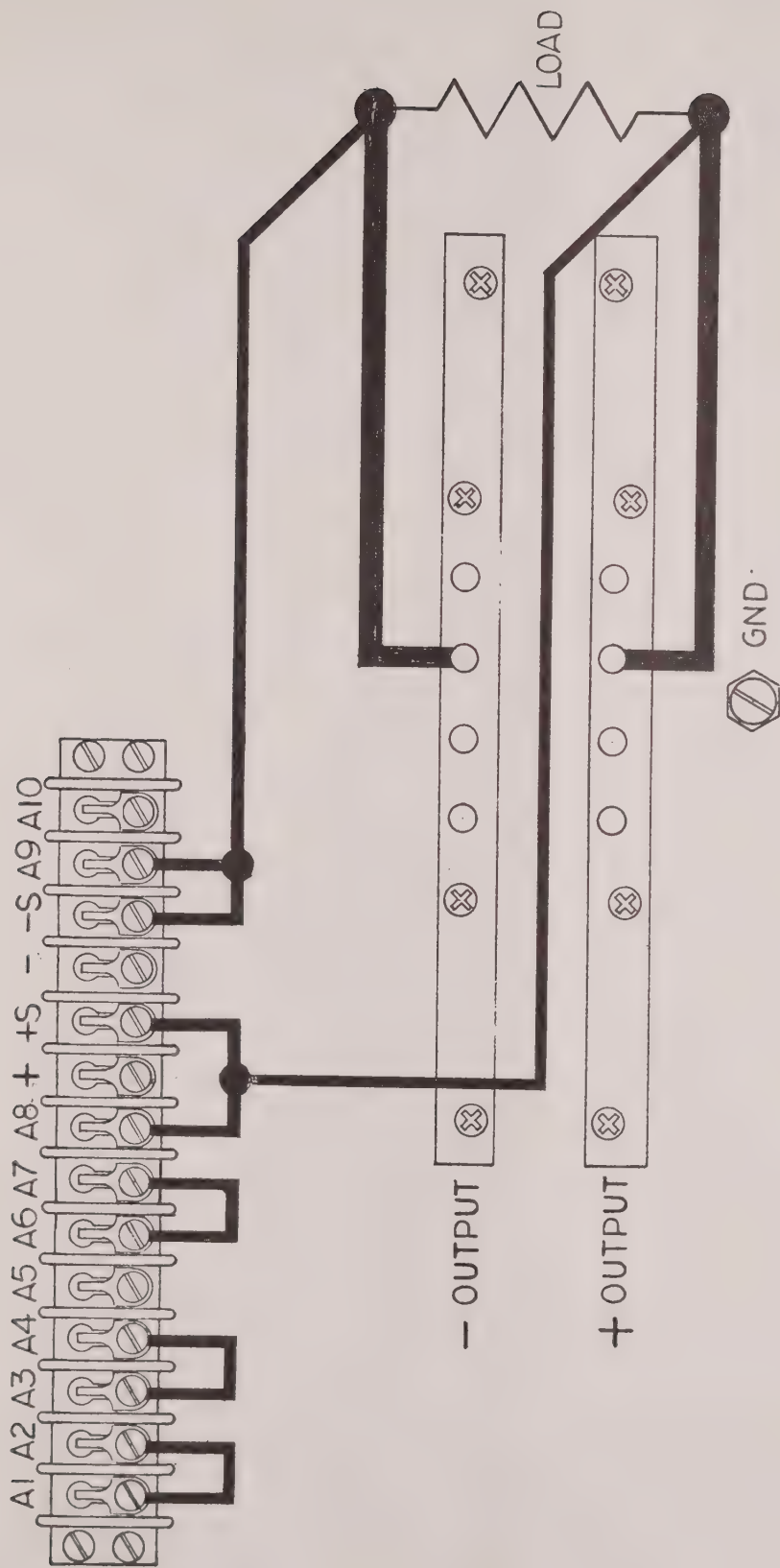
NORMAL STRAPPING

FOR MODEL 6455A FIG 4

HARRISON LABORATORIES
BERKELEY HEIGHTS, N.J.
DIV. OF HEWLETT PACKARD

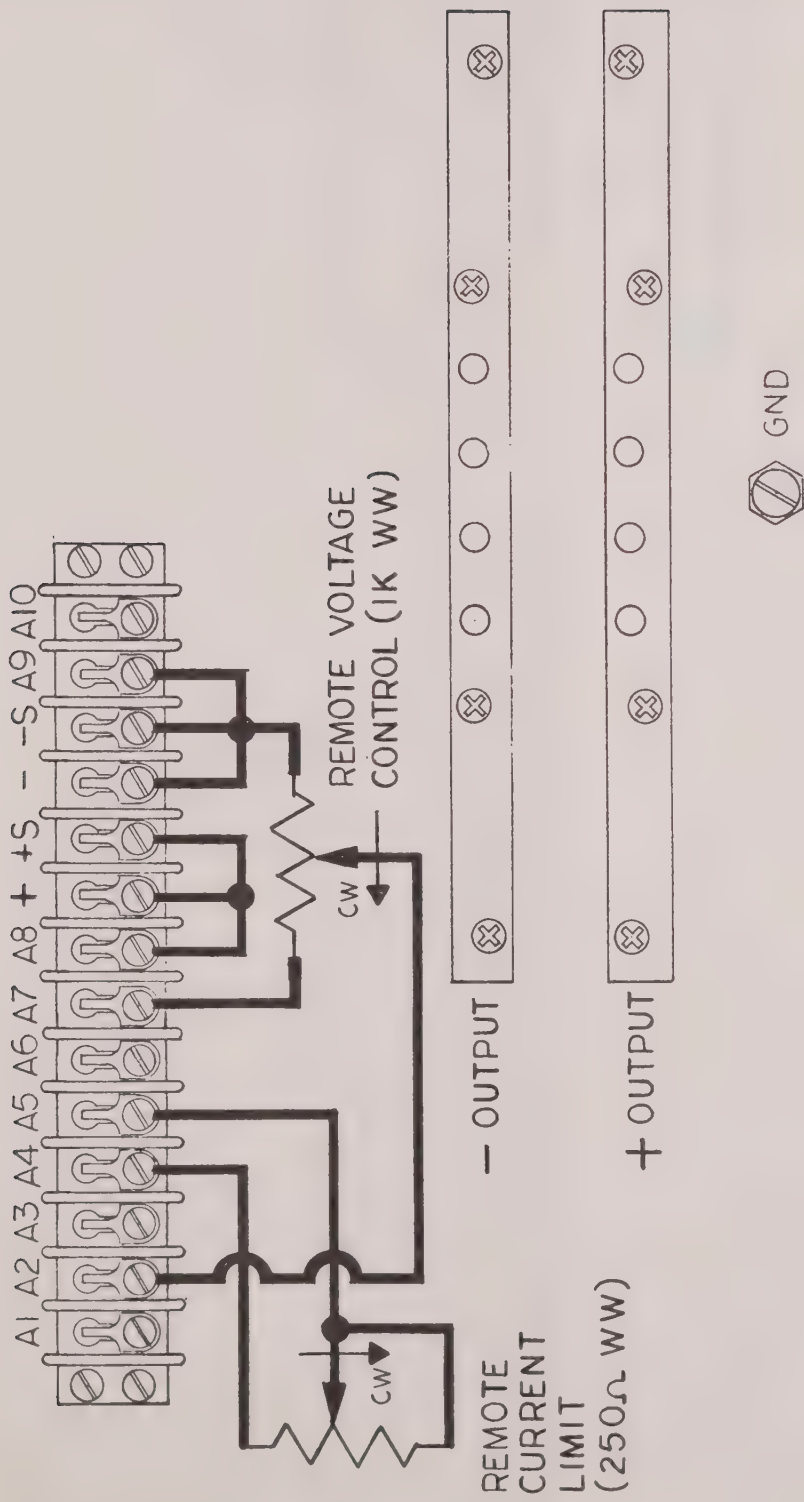
JOB NO.
6455A

DWN 10-5-62
REV A 3-11-63
REVERSE ++S
RUN+



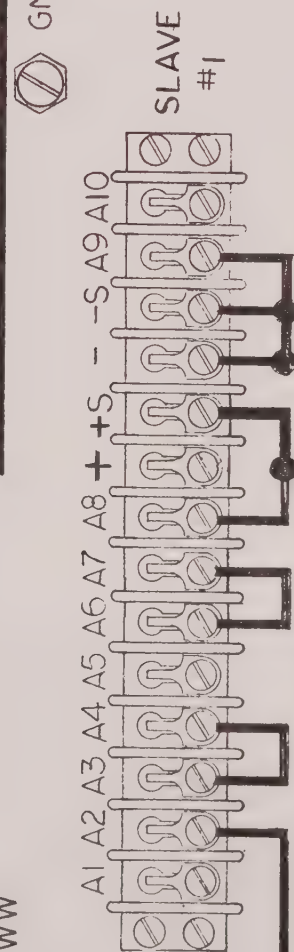
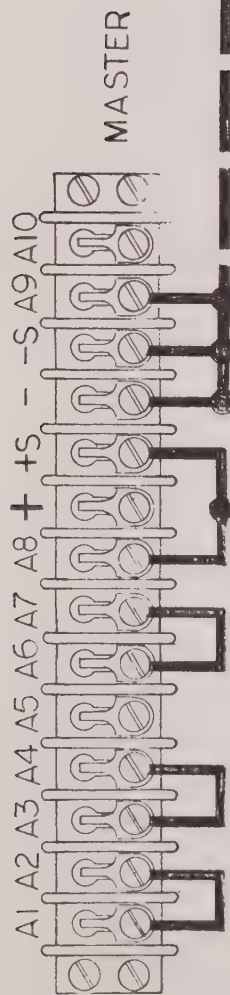
REMOTE SENSING

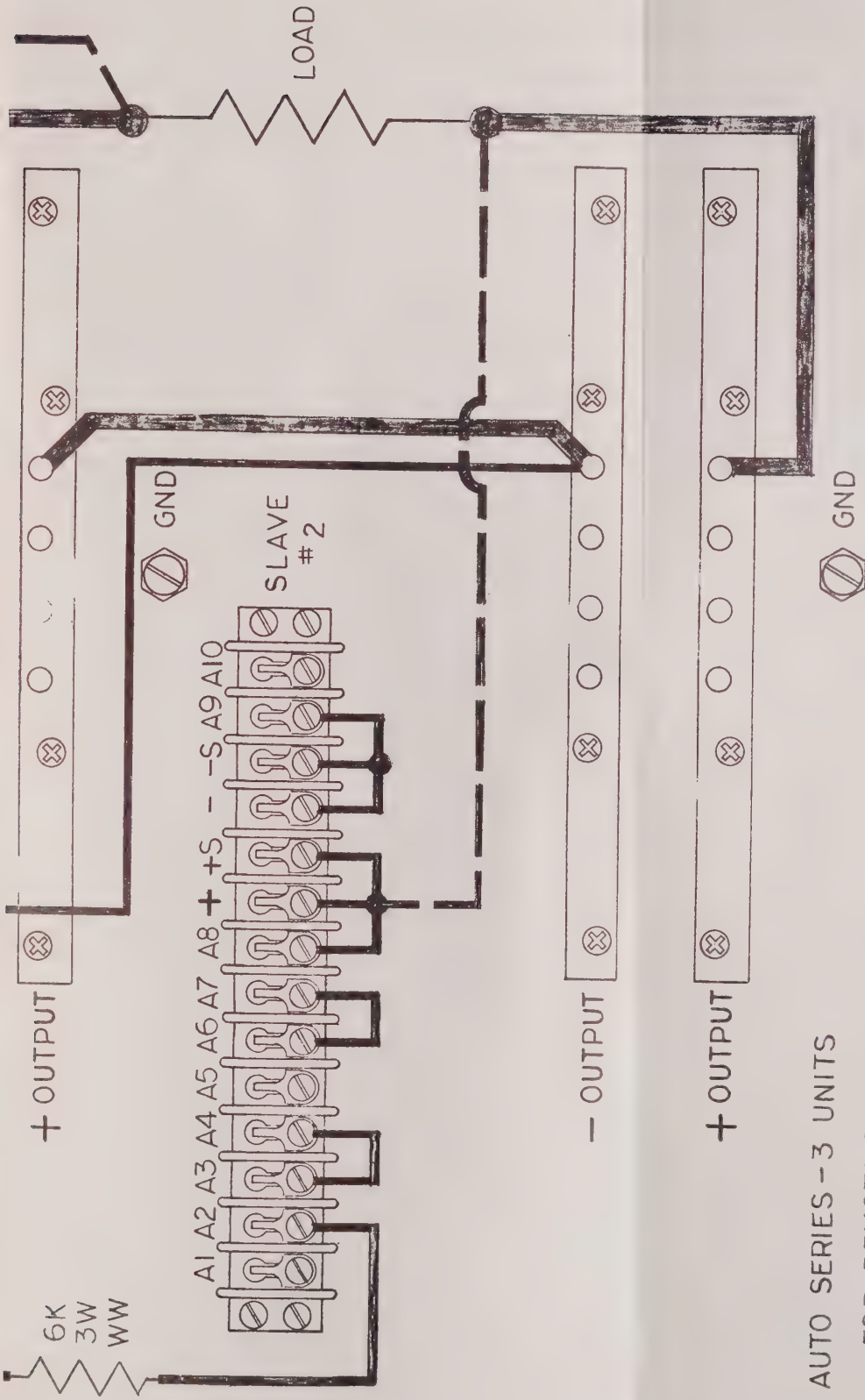
JOB NO. 6455A	DWN 10-5-62 REV A 3-14-63 REVERSE + + + 5 RUN 4	TITLE REMOTE SENSING	
		FOR MODEL 6455A	FIG 5
		HARRISON LABORATORIES BERKELEY HEIGHTS, N.J. DIV. OF HEWLETT PACKARD	



REMOTE PROGRAMMING OF VOLTAGE & CURRENT LOCAL SENSING

J08 NO. 6455A	DWN 10-5-62 REV A 3-14-63 REVERIE + + +5 RUN + TITLE REMOTE PROGRAMMING FOR MODEL 6455A FIG 6 HARRISON LABORATORIES BERKELEY HEIGHTS, N.J. DIV. OF HEWLETT PACKARD
---------------	--





AUTO SERIES - 3 UNITS

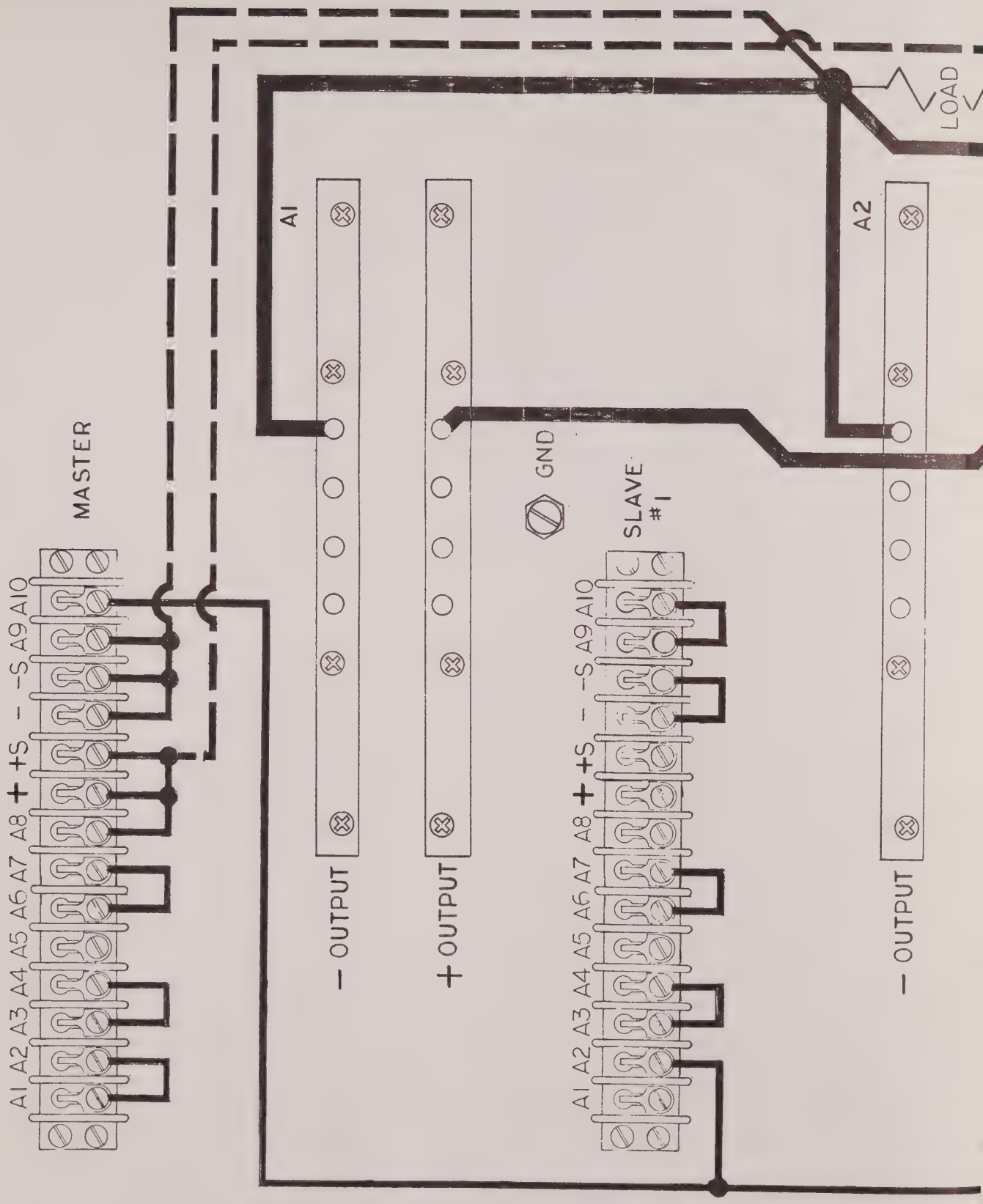
FOR REMOTE SENSING

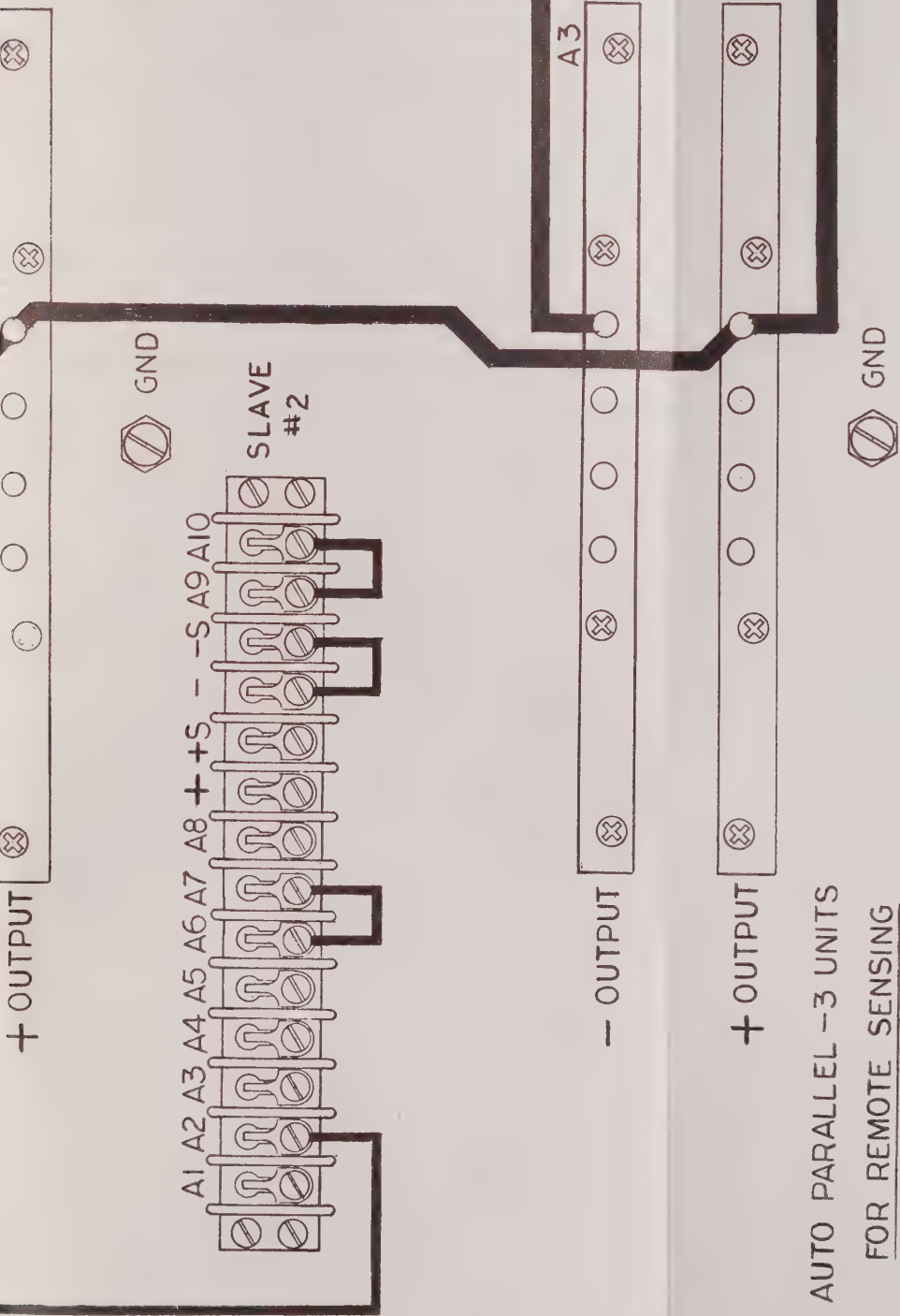
ADD: DASHED SENSING LEADS

REMOVE: -S TO - ON MASTER TERM BOARD

+S TO + ON SLAVE #2 TERM BOARD

JOB NO. 6455A	DWN 10-5-62	REV A 3-19-63 REVERSE +4+5 RUN +
TITLE	AUTO SERIES	FOR MODEL 6455A FIG 7
		HARRISON LABORATORIES BERKELEY HEIGHTS, N.J. DIV. OF HEWLETT PACKARD

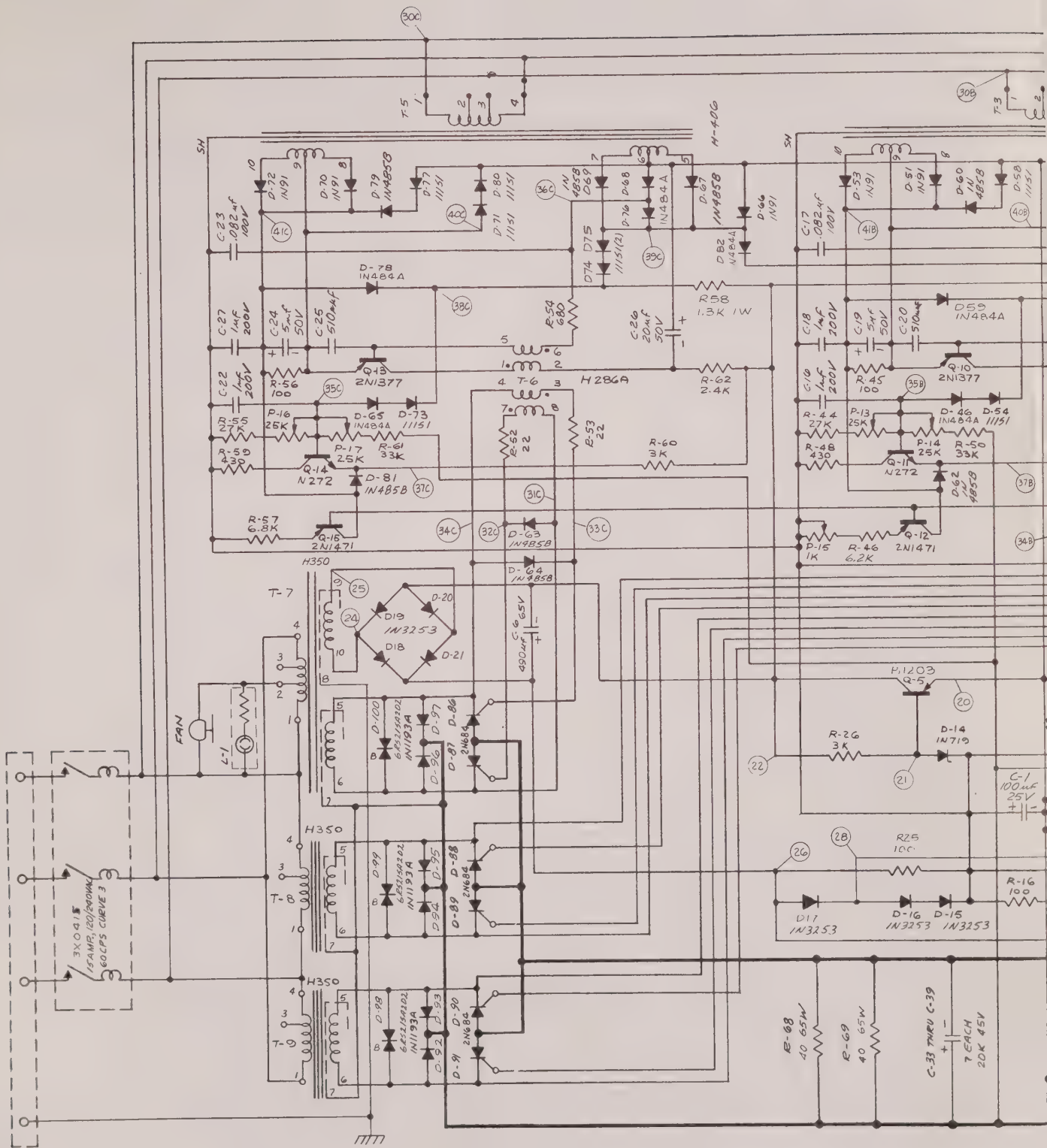




NOTE: LEADS A1, A2, A3 TO
BE EQUAL LENGTH & GAUGE

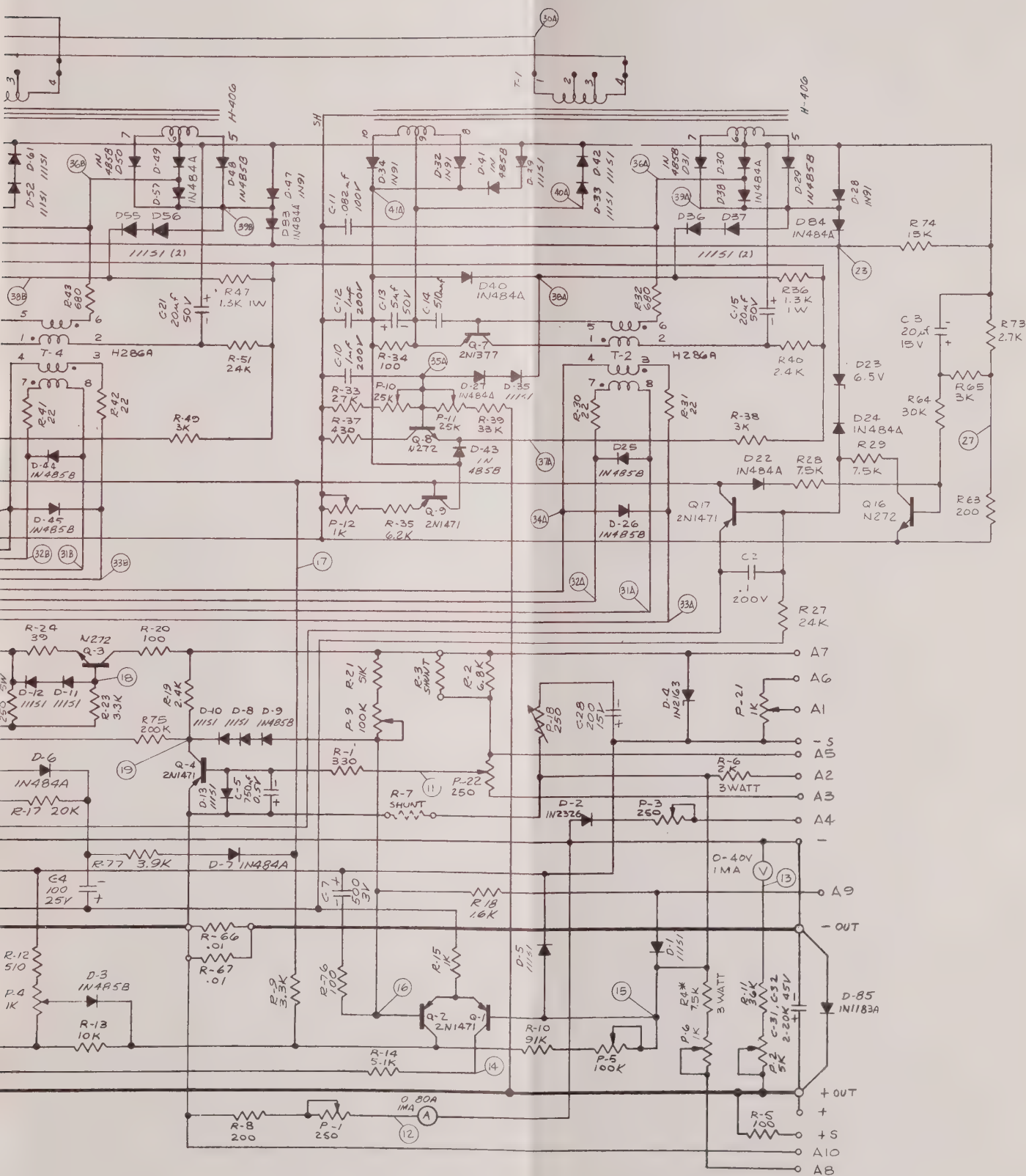
AUTO PARALLEL - 3 UNITS
FOR REMOTE SENSING
ADD: DASHED SENSING LEADS
REMOVE: +S TO + & -S TO -
JUMPERS ON MASTER TERM BOARD

JOB NO.	6455A	DWN 10-5-62	REV A 3-14-63	REVERSE + +S	RUN 4
TITLE	AUTO PARALLEL	FOR MODEL 6455A	FIG 8	HARRISON LABORATORIES	BERKELEY HEIGHTS, N.J.
				DIV. OF	HEWLETT PACKARD



NOTES:

1. NORMAL OPERATION STRAP (A1 & A2)(A3 & A4)(A6 & A7)(A8, + & +5)(A9, - & -5)
2. * DENOTES 20ppm
3. ALL RESISTORS ARE $\frac{1}{2}$ WATT UNLESS OTHERWISE SHOWN
4. NOT USED- Q-6, P-7, 8, 19, 20, C-8, 9, 29, 30
5. R-7 USED WHEN UNITS ARE PARALLELED, OMIT OTHERWISE.



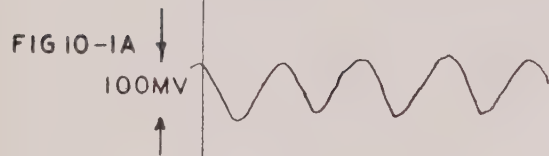
PATENTS APPLIED FOR ON THIS
CIRCUIT LICENSE TO USE MUST
BE OBTAINED IN WRITING FROM
HARRISON LABORATORIES.

JOB NO	6455A	TITLE	SCHEMATIC DIAGRAM
REV	1	DATE	1-15-54
REV	2	DATE	1-15-54
REV	3	DATE	1-15-54
REV	4	DATE	1-15-54
REV	5	DATE	1-15-54
REV	6	DATE	1-15-54
REV	7	DATE	1-15-54
REV	8	DATE	1-15-54
REV	9	DATE	1-15-54
REV	10	DATE	1-15-54
REV	11	DATE	1-15-54
REV	12	DATE	1-15-54
REV	13	DATE	1-15-54
REV	14	DATE	1-15-54
REV	15	DATE	1-15-54
REV	16	DATE	1-15-54
REV	17	DATE	1-15-54
REV	18	DATE	1-15-54
REV	19	DATE	1-15-54
REV	20	DATE	1-15-54
REV	21	DATE	1-15-54
REV	22	DATE	1-15-54
REV	23	DATE	1-15-54
REV	24	DATE	1-15-54
REV	25	DATE	1-15-54
REV	26	DATE	1-15-54
REV	27	DATE	1-15-54
REV	28	DATE	1-15-54
REV	29	DATE	1-15-54
REV	30	DATE	1-15-54
REV	31	DATE	1-15-54
REV	32	DATE	1-15-54
REV	33	DATE	1-15-54
REV	34	DATE	1-15-54
REV	35	DATE	1-15-54
REV	36	DATE	1-15-54
REV	37	DATE	1-15-54
REV	38	DATE	1-15-54
REV	39	DATE	1-15-54
REV	40	DATE	1-15-54
REV	41	DATE	1-15-54
REV	42	DATE	1-15-54
REV	43	DATE	1-15-54
REV	44	DATE	1-15-54
REV	45	DATE	1-15-54
REV	46	DATE	1-15-54
REV	47	DATE	1-15-54
REV	48	DATE	1-15-54
REV	49	DATE	1-15-54
REV	50	DATE	1-15-54
REV	51	DATE	1-15-54
REV	52	DATE	1-15-54
REV	53	DATE	1-15-54
REV	54	DATE	1-15-54
REV	55	DATE	1-15-54
REV	56	DATE	1-15-54
REV	57	DATE	1-15-54
REV	58	DATE	1-15-54
REV	59	DATE	1-15-54
REV	60	DATE	1-15-54
REV	61	DATE	1-15-54
REV	62	DATE	1-15-54
REV	63	DATE	1-15-54
REV	64	DATE	1-15-54
REV	65	DATE	1-15-54
REV	66	DATE	1-15-54
REV	67	DATE	1-15-54
REV	68	DATE	1-15-54
REV	69	DATE	1-15-54
REV	70	DATE	1-15-54
REV	71	DATE	1-15-54
REV	72	DATE	1-15-54
REV	73	DATE	1-15-54
REV	74	DATE	1-15-54
REV	75	DATE	1-15-54
REV	76	DATE	1-15-54
REV	77	DATE	1-15-54
REV	78	DATE	1-15-54
REV	79	DATE	1-15-54
REV	80	DATE	1-15-54
REV	81	DATE	1-15-54
REV	82	DATE	1-15-54
REV	83	DATE	1-15-54
REV	84	DATE	1-15-54
REV	85	DATE	1-15-54
REV	86	DATE	1-15-54
REV	87	DATE	1-15-54
REV	88	DATE	1-15-54
REV	89	DATE	1-15-54
REV	90	DATE	1-15-54
REV	91	DATE	1-15-54
REV	92	DATE	1-15-54
REV	93	DATE	1-15-54
REV	94	DATE	1-15-54
REV	95	DATE	1-15-54
REV	96	DATE	1-15-54
REV	97	DATE	1-15-54
REV	98	DATE	1-15-54
REV	99	DATE	1-15-54
REV	100	DATE	1-15-54

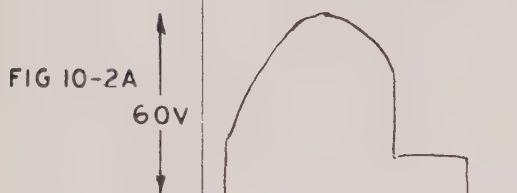
10 VOLTS
20 AMPS
(200 WATTS)

OUTPUT
(INTO 0.5 OHM
LOAD)

36 VOLTS
72 AMPS
(2600 WATTS)



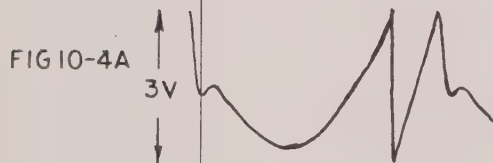
OUTPUT
RIPPLE
(+ TO -)



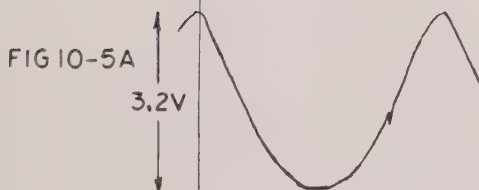
[31 TO 34] (A,B,C)



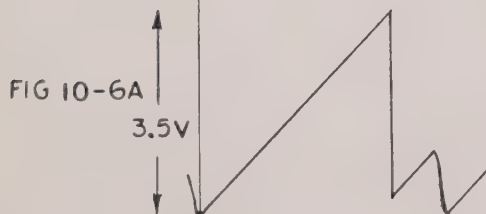
[32 TO 31]
[33 TO 34] (A,B,C)



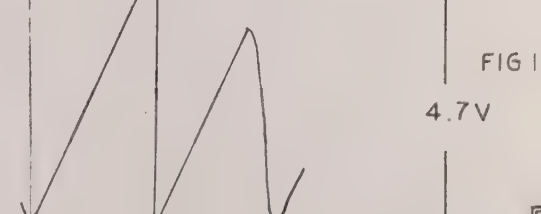
(40 (A,B,C) TO -)



[40 TO 41] (A,B,C)

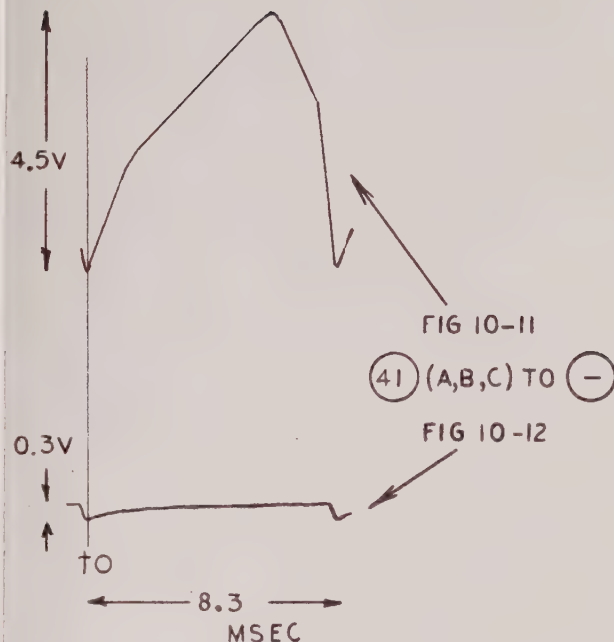
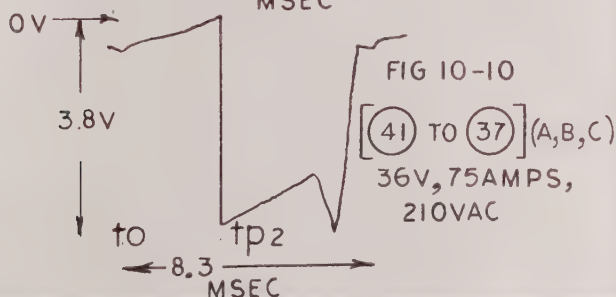
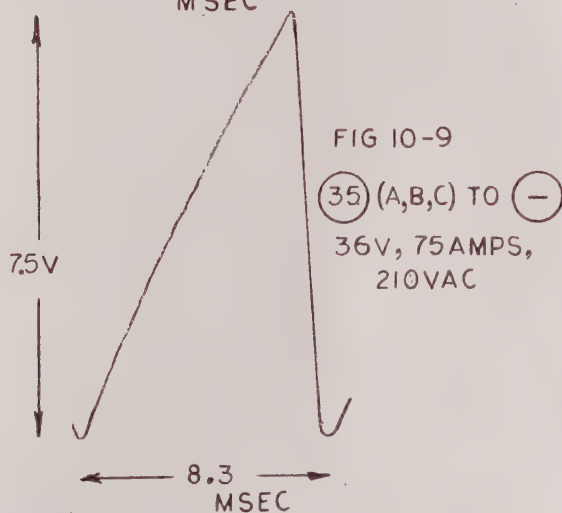
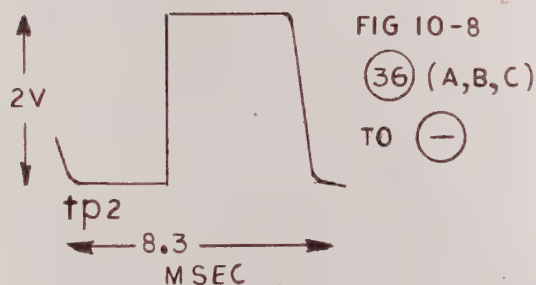
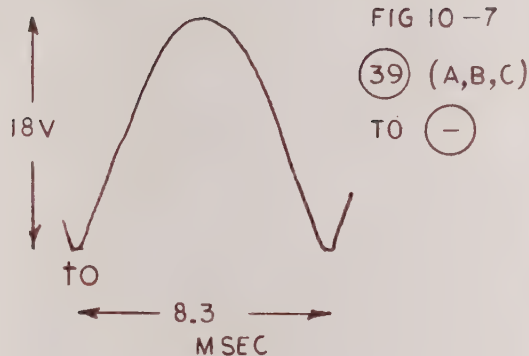


(41 (A,B,C) TO -)



to tp1
8.3
MSEC

to tp2
8.3
MSEC

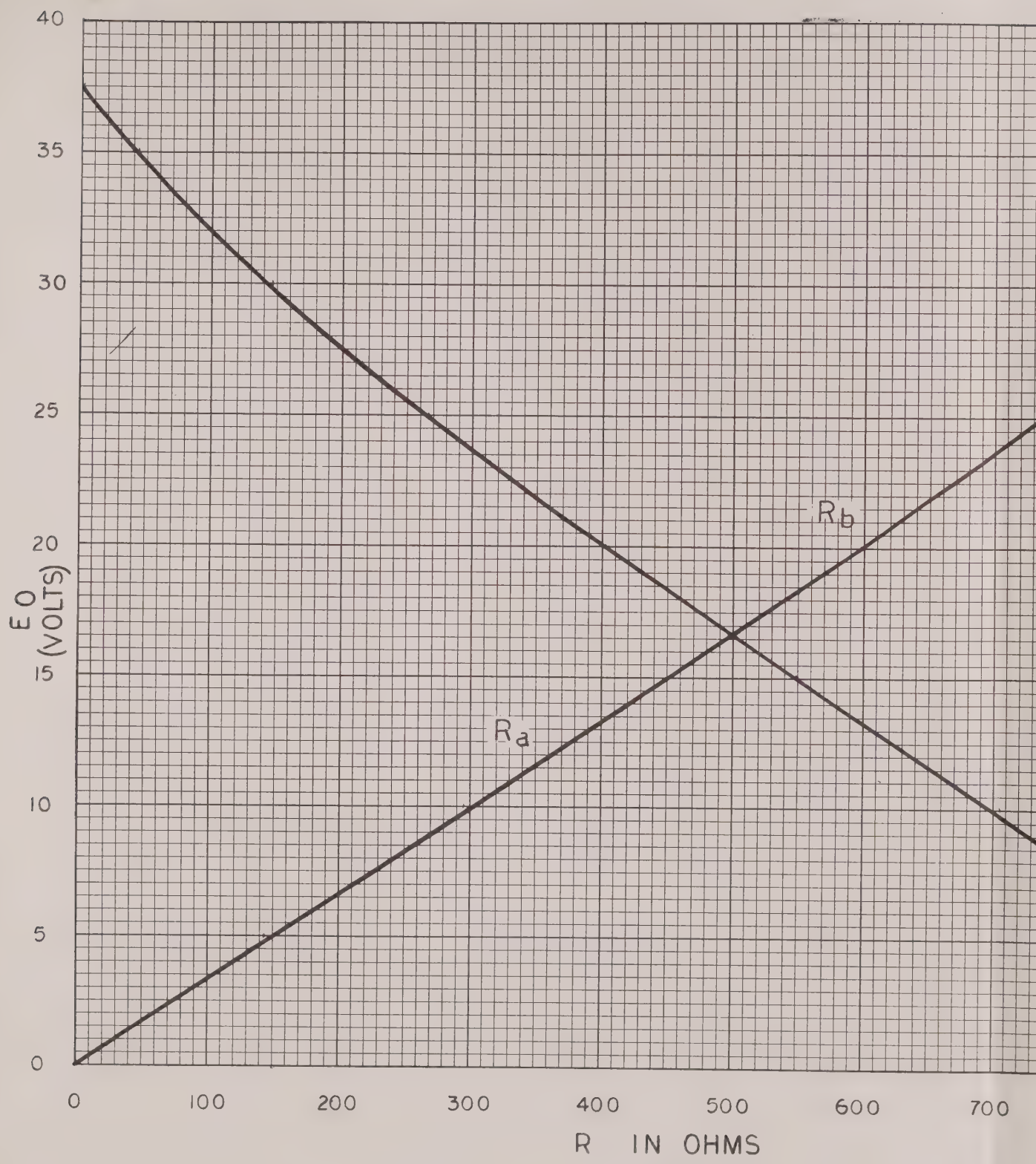


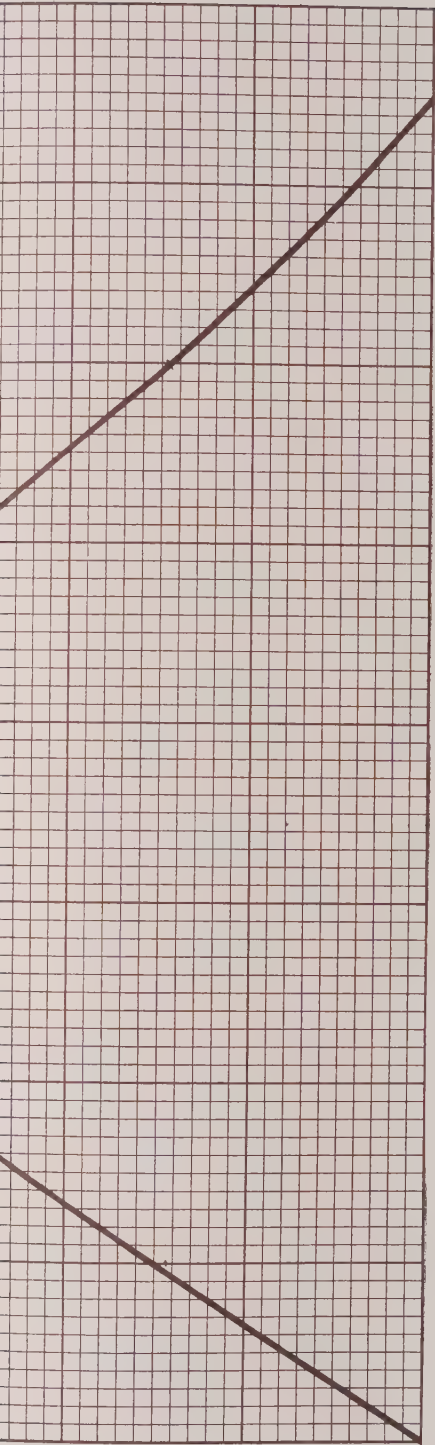
NOTES:

1. All waveforms are typical at medium (220 VAC) input line voltage except as otherwise indicated.
2. All waveforms as measured on H-P 130B Oscilloscope with AC coupling to vertical amplifier except figure 10-10 (DC coupled).
3. Oscilloscope line cord connected to power source thru 3 to 2 connector, lower vertical amplifier input terminal connected to ground.
4. For indicated polarity connect first test point to upper input terminal of vertical amplifier, connect second test point to scope ground (chassis).
5. Test points followed by (A, B, C) indicates point exists in each of three firing circuits. Waveshapes will be similar in amplitude and shape (for any given operating point), but will be different in phase by 120 electrical degrees.

HARRISON LABORATORIES, INC.
 45 INDUSTRIAL ROAD
 BERKELEY HEIGHTS, N. J.

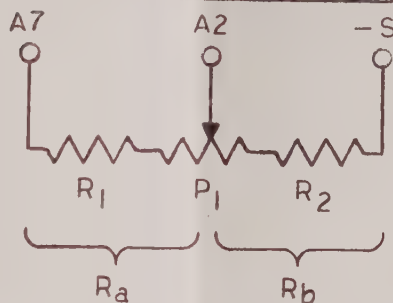
TITLE FIG 10 MODEL 6455A
 TYPICAL WAVEFORMS





800 900 1K

SINGLE OUTPUT VOLTAGE



$$R_1 + P_1 + R_2 = 1000\Omega$$

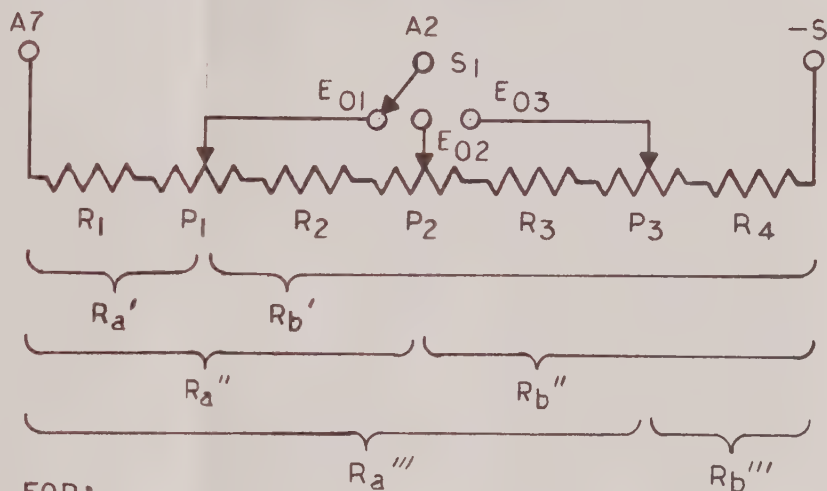
$$R_a = R_1 + \frac{P_1}{2}$$

$$R_b = R_2 + \frac{P_1}{2}$$

$$P_1 = 50\Omega$$

R_1 & R_2 ARE $\pm 1\%$

MULTIPLE OUTPUT VOLTAGE



FOR:

$$E_{01} \quad R_a' = R_1 + \frac{P_1}{2}$$

$$R_b' = \frac{P_1}{2} + R_2 + P_2 + R_3 + P_3 + R_4$$

$$E_{02} \quad R_a'' = R_1 + P_1 + R_2 + \frac{P_2}{2}$$

$$R_b'' = \frac{P_2}{2} + R_3 + P_3 + R_4$$

$$E_{03} \quad R_a''' = R_1 + P_1 + R_2 + P_2 + R_3 + \frac{P_3}{2}$$

$$R_b''' = \frac{P_3}{2} + R_4$$

$$R_1 + P_1 + R_2 + P_2 + R_3 + P_3 + R_4 = 1000\Omega$$

$$P_1, P_2, P_3 = 50\Omega$$

R_1, R_2, R_3, R_4 ARE $\pm 1\%$

S_1 — SHORTING CONTACTS

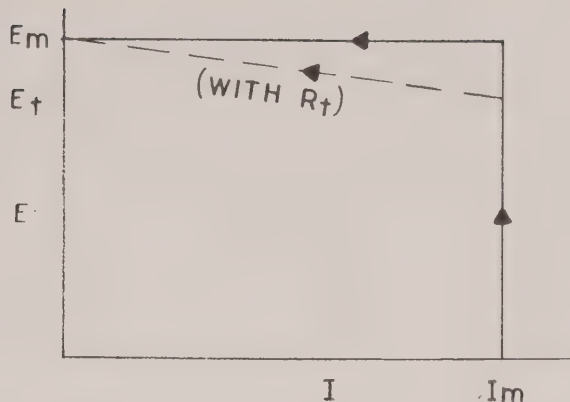
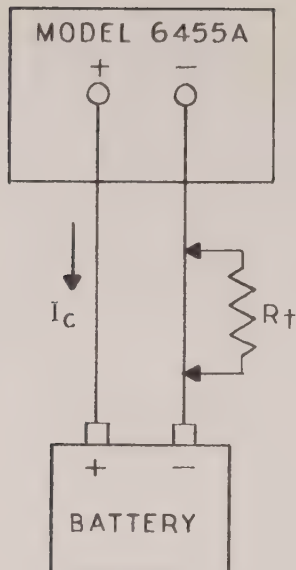
JOB NO.
6455A

DWN 10 - 15-62

TITLE FIXED RESISTOR
PROGRAMMING

FOR
MODEL 6455A FIG 11

HARRISON LABORATORIES
BERKELEY HEIGHTS, N. J.
DIV. OF HEWLETT - PACKARD



E_m = BATTERY FULL CHARGE VOLTAGE

I_m = CONSTANT CURRENT CHARGE RATE

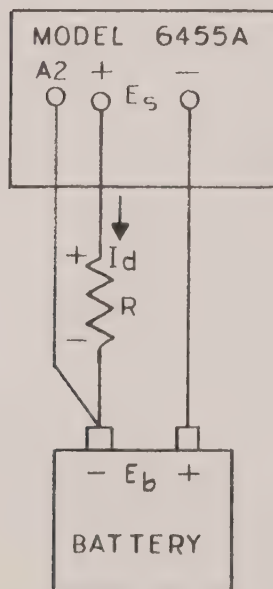
E_t = BATTERY VOLTAGE AT WHICH CHARGE RATE WILL BEGIN TO TAPER (WITH INSERTION OF R_t)

$$R_t = E_m \frac{E_t}{I_m}$$

I_c = CHARGE CURRENT

CHARGING

REMOVE JUMPERS: A1 TO A2 ; A8 TO +S



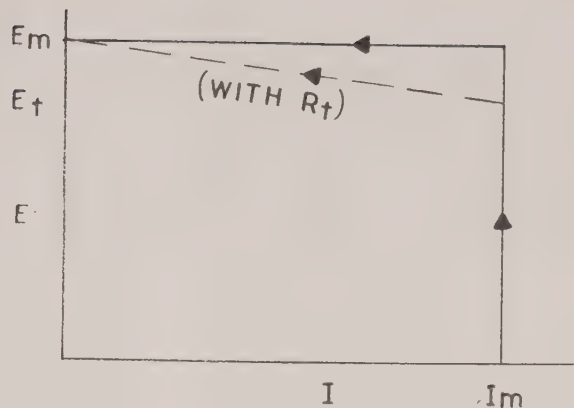
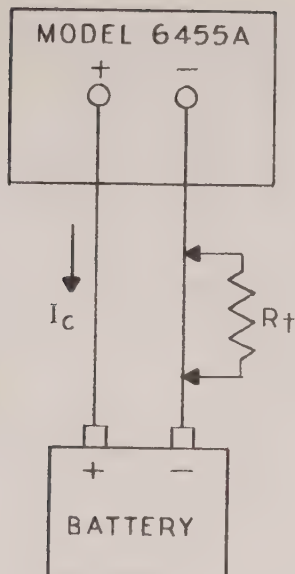
$I_d = 75A$ = DISCHARGE CURRENT RATE

$$R = \frac{E_b}{I_d} \text{ BUT } RI_d \leq 36V$$

CAUTION INSURE THAT ALL LEADS ARE SECURE BEFORE ENERGIZING MODEL 6455A. OPEN LEAD COULD CAUSE E_s TO RISE BEYOND SAFE LIMITS

I_d DISCHARGE CURRENT

DISCHARGING



E_m = BATTERY FULL CHARGE VOLTAGE

I_m = CONSTANT CURRENT CHARGE RATE

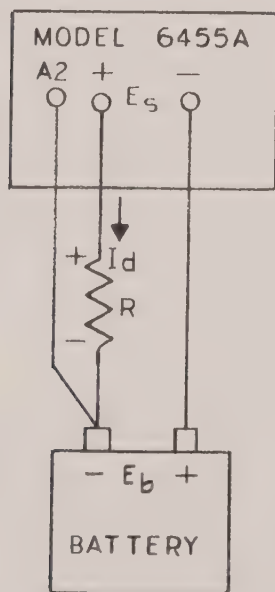
E_t = BATTERY VOLTAGE AT WHICH CHARGE RATE WILL BEGIN TO TAPER (WITH INSERTION OF R_t)

$$R_t = E_m \frac{E_t}{I_m}$$

I_c = CHARGE CURRENT

CHARGING

REMOVE JUMPERS: A1 TO A2 ; A8 TO +S



$I_d = 75A$ = DISCHARGE CURRENT RATE

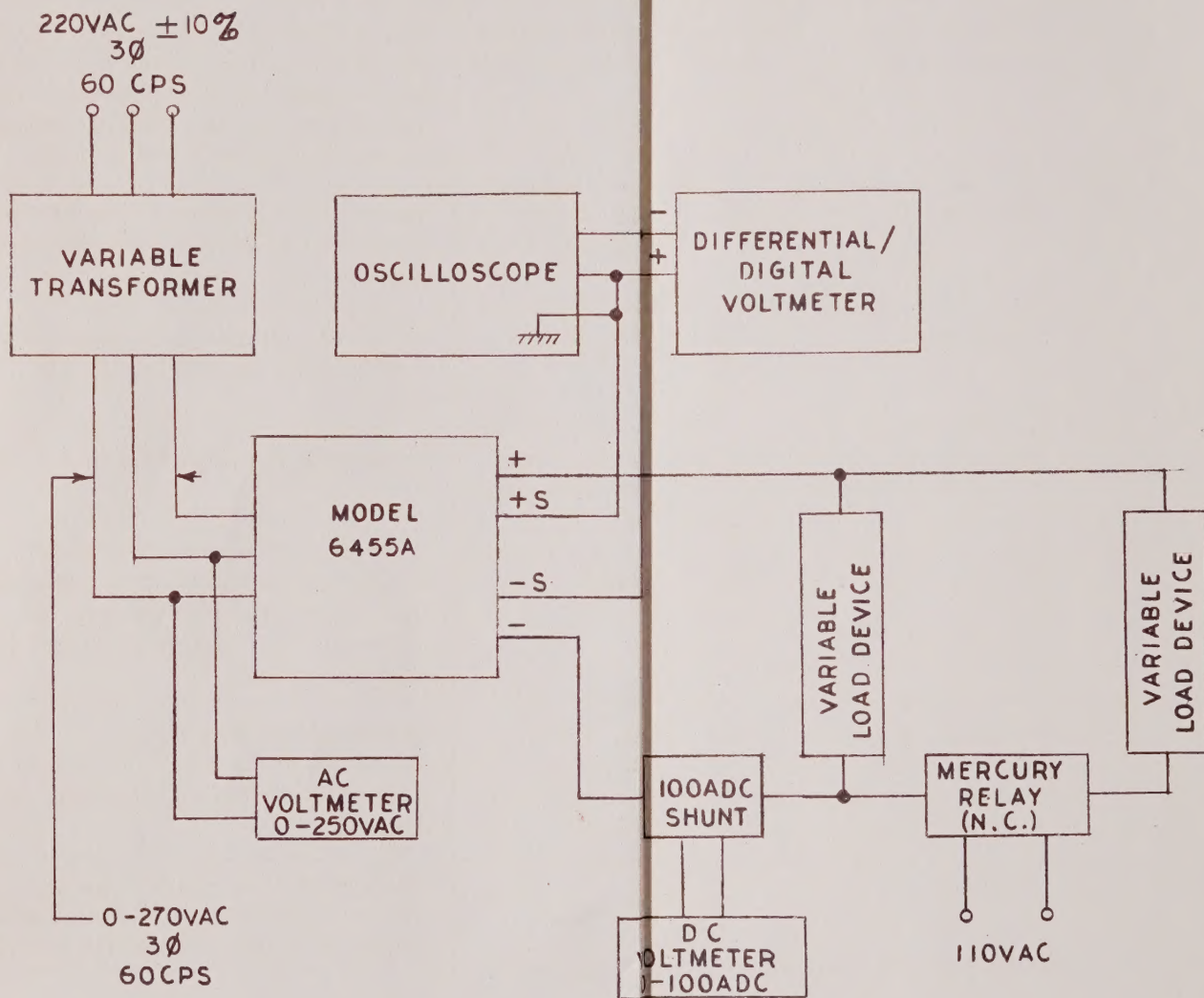
$$R = \frac{E_b}{I_d} \text{ BUT } R I_d \leq 36V$$

CAUTION INSURE THAT ALL LEADS ARE SECURE BEFORE ENERGIZING MODEL 6455A. OPEN LEAD COULD CAUSE E_s TO RISE BEYOND SAFE LIMITS

I_d DISCHARGE CURRENT

DISCHARGING

ITEM	INSTRUMENT	RECOMMENDED TYPE	CHARACTERISTIC AND/OR USE
1	Variable Transformer	General Radio Variac No. W30HC2	6.5 KVA - open delta - 0-270 VAC
2	Variable Load Devices (2)	Rex Rheostat Company No. 2359 & No. 2360	No. 2359-5.4/1.35 ohms @ 17/34 ADC No. 2360-3/0.75 ohms @ 22/44 ADC Each connected for maximum current & both connected in parallel across the output terminals of the supply.
3	Ammeter	Simpson No. 0560 ammeter & No. 6713 shunt	0-100 ADC ammeter & 100 ADC shunt - connected in series between load & supply.
4	Voltmeter	Simpson No. 8800	0-250 VAC voltmeter - connected between two of test points 30A, 30B, & 30C.
5	Differential or Digital Voltmeter	John Fluke Co., Inc. No. 801H differential voltmeter.	Connected between +S and -S.
6	Oscilloscope	 No. 130B/C	Connected as directed to power supply, line power to scope through 3:2 connector, vertical amplifier grounded to chassis ground.
7	Decade Resistor	Precise No. 468	Connected as directed.
8	Mercury Relay, Plunger Type	Ebert No. HD-2 @ 115 VAC Coil	Connected in series with No. 2360 load device.
9	Shorting Strap		Fabricated from copper bus strap or No. 8 wire - connected as directed across output in series with meter shunt.



WIRING DIAGRAM FOR MINIMUM FIRING ANGLE ADJUSTMENT

JOB NO.
MODEL 6455A
DWN 11-1-62

HARRISON LABORATORIES, INC.

45 INDUSTRIAL ROAD
BERKELEY HEIGHTS, N. J.

TITLE FIG 13 MODEL 6455A
TEST EQUIPMENT LIST &
TYPICAL WIRING DIAGRAM

Warranty

Harrison Laboratories, a division of Hewlett-Packard Company, warrants each instrument manufactured by them to be free from defects in material and workmanship. Our liability under this warranty is limited to servicing or adjusting any instrument returned to the factory for that purpose and to replacing any defective parts thereof; electron tubes, fuses, and batteries are specifically excluded from any warranty. This warranty is effective for one year after delivery to the original purchaser when the instrument is returned, transportation charges prepaid by the original purchaser, and when upon our examination it is disclosed to our satisfaction to be defective. Our warranty for this instrument is rendered void if the unit has been modified, unless such changes have been made in accordance with written instructions received from Harrison Laboratories. If the fault has been caused by misuse or abnormal conditions of operation, or results from use in combination with any other items, repairs will be billed at cost. In this case, an estimate will be submitted before the work is started.

IF ANY FAULT DEVELOPS,
THE FOLLOWING STEPS SHOULD BE TAKEN :

- A. Notify us, giving full details of the difficulty, and include the model number and serial number of the equipment. On receipt of this information, we will give you service data or shipping instructions. Do not return unit for repair without first contacting factory or sales representative for instructions.
- B. On receipt of shipping instructions, forward the instrument prepaid to the factory. If requested, an estimate of the charges will be made before the work begins, provided the instrument is not covered by the warranty.
- C. If the original carton and packing are not available, the instrument should be packed in a strong exterior container and surrounded by two or three inches of excelsior or similar shock-absorbing material. We advise that all returned equipment should be declared at full value to the carrier.

Harrison Laboratories reserves the right to make changes in design at any time without incurring any obligation to install same on units previously purchased.

This warranty is expressly in lieu of all other obligations or liabilities on the part of Harrison Laboratories, and Harrison Laboratories neither assumes, nor authorizes any other person to assume for it, any liability in connection with the sales of Harrison Laboratories instruments.

MP MASTER



MA27224